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TENNESSEE VALLEY AUTHORITY

Division of Environmental Research and Development

FULL-SCALE STUDY OF PLUME RISE AT LARGE ELECTRIC GENERATING STATIONS

Bull Run Supplement

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The purpose was to develop a practical, data-based procedure for estimating effective plume rise and plume rise versus distance. The results are presented of an investigation of the relationships of the meteorological, plant design, and operating conditions to the: initial plume rise within 152 meters from the source; rate of plume rise with downwind distance; and distance where the maximum rise occurs. More than 1,100 photographs were used in this evaluation, incorporating special methods. The rate of plume rise with downwind distance depends on the atmospheric stability with the effective rise depending on the initial rise within about 150 meters from the source. This initial rise is a function of stack design and emission parameters and mean wind speed between stack top and plume top. Stack height affects the effective plume rise only because of the possibility of releasing the stack effluent into different meteorological regimes since the meteorological parameters are defined from stack top to plume top. For a known stability range, an expression may be determined for estimating the effective plume rise at various distances from the stack. An equation for estimating the effective plume rise at any downwind distance up to 3,000 meters during neutral conditions, stable conditions, and very stable conditions is determined. For a selected downwind distance, an expression is determined for estimating the effective plume rise during any stability conditions.

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FULL-SCALE STUDY OF PLUME RISE AT LARGE ELECTRIC GENERATING STATIONS BULL RUN SUPPLEMENT

SUMMARY

A principal requirement in determining potential surface concentration of stack emissions from large coal-fired power plants is the sum of actual stack height and vertical displacement of the plume (effective plume rise) when the rate of rise of the plume centerline as a function of distance reaches a selected value. Also important is the distance from the source where the effective plume rise occurs. However, much ambiguity exists in present methods for estimating effective plume rise for a specific downwind distance. Therefore, with almost ten years of experience in the study of plume rise, the Tennessee Valley Authority (TVA) has combined the plume rise data obtained during single stack operations at three coal-fired power plants encompassing a range of stack heights.

The purpose of this work was to develop a practical, data-based procedure for estimating effective plume rise and plume rise versus distance. This report presents the results of an investigation of the relationships of the meteorological, plant design, and operating conditions to the:

1. Initial plume rise within 152 meters from the source,
2. Rate of plume rise with downwind distance,
3. Distance where the maximum rise occurs.

More than 1,100 photographs were used in this evaluation, incorporating special "photometric" methods developed by TVA. It is demonstrated that the

rate of plume rise with downwind distance depends on the atmospheric stability with the effective rise depending on the initial rise within about 150 meters from the source. This initial rise is a function of stack design and emission parameters and mean wind speed between stack top and plume top. It is also indicated that stack height affects the effective plume rise only because of the possibility of releasing the stack effluent into different meteorological regimes since the meteorological parameters are defined from stack top to plume top.

Results of this evaluation indicate that for a known stability range, an expression may be determined for estimating the effective plume rise at various distances from the stack.

An equation for estimating the effective plume rise, Δh, at downwind distance, x, up to 3,000 meters during neutral conditions ($-0.17 < \Delta\theta/\Delta z \leq 0.16$, average = 0.05) °C/100 m, is determined as:

$$\Delta h = 2.50\ x^{0.56}\ F^{1/3}\ \bar{u}^{-1}$$

For moderately stable conditions ($0.16 < \Delta\theta/\Delta z \leq 0.70$, average = 0.43) °C/100 m, for distance, x, up to 2,800 meters:

$$\Delta h = 3.75\ x^{0.49}\ F^{1/3}\ \bar{u}^{-1}$$

Very stable conditions ($0.70 < \Delta\theta/\Delta z \leq 1.87$, average = 1.06) °C/100 m, and distance, x, up to 1,960 meters:

$$\Delta h = 13.8\ x^{0.26}\ F^{1/3}\ \bar{u}^{-1}$$

However, for a selected downwind distance, an expression may be determined for estimating the effective plume rise during any stability conditions. An applicable distance at TVA power plants was selected at 1,824 meters which resulted in the equation:

$$\Delta h = 173 \frac{F^{1/3}}{\bar{u} \exp\left[0.64 \frac{\Delta\theta}{\Delta z}\right]}$$

or for neutral conditions, i.e., $\Delta\theta/\Delta z = 0$:

$$\Delta h = 173 \frac{F^{1/3}}{\bar{u}} .$$

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FULL-SCALE STUDY OF PLUME RISE AT LARGE ELECTRIC GENERATING STATIONS BULL RUN SUPPLEMENT*

1.0 INTRODUCTION

The Tennessee Valley Authority (TVA), under sponsorship of the Environmental Protection Agency (EPA), completed a comprehensive 3-year research project in 1966 entitled "Full-Scale Study of Plume Rise at Large Electric Generating Stations." The project report[1] included over 1,500 observations of plume rise during various meteorological and operational conditions involving unit ratings ranging from 173 to 704 megawatts (mw) with stack heights varying from 76 to 183 meters. Also included was an evaluation of plume rise observations with respect to six plume rise formulas in general use: Holland[2]; Bosanquet, Carey, and Halton[3]; Davidson-Bryant[4]; Csanady[5]; CONCAWE (Brummage, et al.)[6]; and Lucas, Moore, and Spurr[7].

A later investigation of these plume rise observations was presented in a paper[8] in 1970 entitled "Plume Rise Estimates for Electric Generating Stations." Results of this later evaluation indicated better agreement of plume rise estimations with observations was obtained using a modification of Briggs's "2/3 power law[9]." This equation, with a stability parameter, embodies the physical quantities, i.e., stack configuration and emission parameters, associated with plume rise and permits accounting for differences in plume rise attributed to variations in atmospheric stability.

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*Report prepared by Thomas L. Montgomery, Assistant Chief, Air Quality Branch; S. B. Carpenter, Supervisor, Air Quality Studies Section; William C. Colbaugh, Research Analyst; and Fred W. Thomas, Chief, Air Quality Branch.

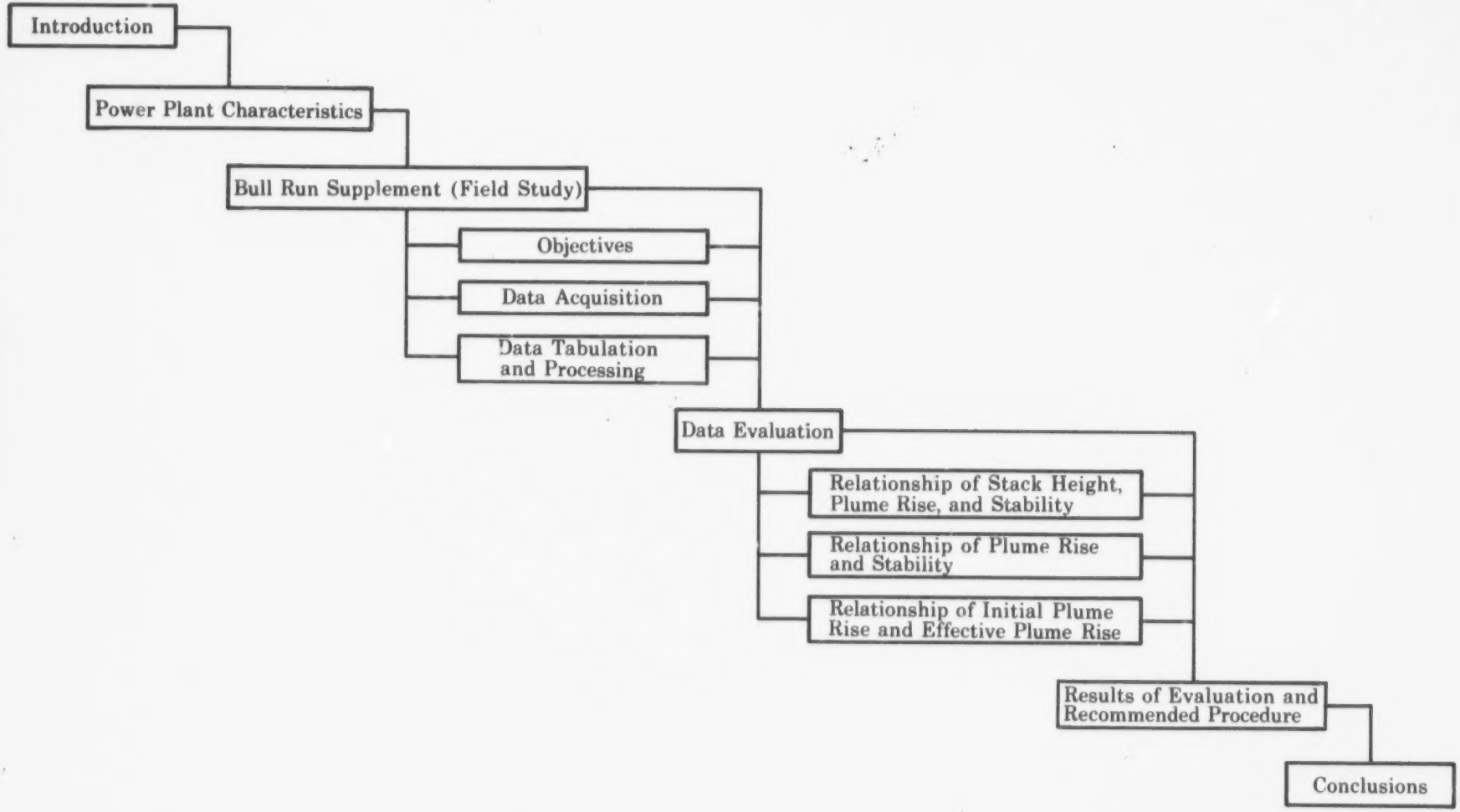
However, a progressive trend of increasing unit sizes and stack heights at modern power plants necessitated further study and analyses of plume rise; therefore, during 1967-69, TVA collected additional plume rise information at the Bull Run power plant--one 950-mw unit with a 244-meter stack. These observations were combined and evaluated with the data obtained when only one stack was being used at a power plant during the previous study[1].

The purpose of this report is to present the results of an investigation of the relationships of stack height, plume rise, and atmospheric stability. Also discussed are the objectives and methodology of data acquisition and processing for the Bull Run field study. This work was performed to develop a practical, data-based procedure for estimating effective plume rise and plume rise versus distance. The organization of the discussion is shown in plate 1.

2.0 POWER PLANT CHARACTERISTICS

Plume rise observations made at three coal-fired power plants are included in this plume rise evaluation encompassing a range of stack heights. Characteristics, shown in table 1, include number of units, rated plant capacity, number of stacks, stack dimensions, and exit temperature of flue gas.

The Paradise power plant, figure 1, is located on the south bank of Green River, 13 kilometers east-southeast of Central City, Kentucky. Although the plant has two 704-mw units with two 183-meter stacks and one 1,150-mw unit with a 244-meter stack, only those observations made during single stack operations were used for this evaluation.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Data Evaluation
Relationship of Stack Height, Plume Rise, and Stability
Relationship of Plume Rise and Stability
Relationship of Initial Plume Rise and Effective Plume Rise
Results of Evaluation and Recommended Procedure
Conclusions

DISCUSSION ORGANIZATION

Plate 1

Other single stack data were obtained from observations made at the Gallatin power plant, figure 2. Located on the northeast bank of Cumberland River, 8 kilometers southeast of Gallatin, Tennessee, the plant has four 314-mw units with two 152-meter stacks.

The more recent plume rise observations were obtained at the Bull Run power plant, figure 3. Bull Run is located on the Melton Hill Reservoir, 8 kilometers east of Oak Ridge, Tennessee, and has one 900-mw unit with a 244-meter stack.

3.0 BULL RUN SUPPLEMENT (FIELD STUDY)

The Tennessee Valley Authority, under sponsorship of the Environmental Protection Agency - Office of Air Programs, conducted a comprehensive research project at the Bull Run power plant during the period 1967-69. The methodology and objectives of the data acquisition and processing program are discussed in this section.

3.1 Objectives

The objective of the comprehensive field study at the Bull Run power plant was to obtain sufficient field observations and operational information to relate actual plume rise to meteorological and operational factors at a large coal-fired power plant with a single high stack. "High stack" refers to a stack higher than observed during previous studies, i.e., 244 meters.

3.2 Data Acquisition

A comprehensive field data acquisition program included three general categories of information: (1) power plant operations, (2) meteorological conditions, and (3) plume characteristics.

3.2.1 Power Plant Operations

All routine operational data kept at the power plant were available for the study. Also, every 30 minutes during the sampling period coal samples were collected.

3.2.2 Meteorological Conditions

Local meteorological conditions were identified periodically each day with on-site observations. General synoptic weather conditions for each sampling day were identified from the Nashville, Tennessee, rawinsonde data and from the daily meteorological charts provided by the NOAA National Weather Service.

Wind information was obtained at 30-minute intervals by the release of pilot balloons. Helicopter flights provided vertical temperature information from the surface to elevations well above the plume top. Flights were made at 1-hour intervals in the immediate plume area upwind of the stack to obtain individual temperature readings at 30-meter intervals.

Additional surface meteorological information, i.e., wind direction and speed, and dry-bulb temperature, was recorded prior to each pilot balloon release. Cloud coverage and other general weather observations were recorded routinely throughout the sampling period.

3.2.3 Plume Characteristics

The objective of this phase of the data acquisition program was to define plume configurations resulting from various combinations of emission and meteorological conditions. Two separate, simultaneous field measurement techniques were used--surface photography and aerial surveillance by helicopter.

3.2.3.1 Surface Photographic Technique--The surface photographic technique was used to document plume configuration with two cameras operating simultaneously at 5-minute intervals. The cameras were mounted on modified transit heads and located at referenced sites as shown in figure 4, usually 3 to 5 kilometers from the stack where right angular orientation to the plume path could be approximated.

3.2.3.2 Aerial Surveillance Technique--Supplementing the surface photography was a series of hourly aerial observations at intervals of 0.8- and 1.6-km downwind from the stack. The elevation of plume top and bottom was determined by relating visual observations to altitude readings. Direction of plume travel was continuously determined and this information used to assist in locating the camera crews.

3.3 Data Tabulation and Processing

All photographs, charts, recordings, data sheets, and observations were labeled, correlated, and organized for each day of sampling. These data were then reduced and displayed for analysis and evaluation. Either direct measurements or reliable estimates were made of the parameters needed for an evaluation of plume rise. This information is indicated in table 2 for the Bull Run power plant and for the observations made during single stack operations at the Paradise and Gallatin power plants.

3.3.1 Power Plant Operations

The 30-minute coal samples were composited for a daily proximate analysis providing information on moisture, volatile matter, fixed carbon, ash, and sulfur. This information was then used in conjunction with values obtained for the excess air, temperature of exit gas, and inside radius of stack to calculate, on a daily basis, the stack gas velocity and density.

3.3.2 Meteorological Conditions

Information necessary to determine vertical profiles of wind direction and speed was obtained by processing the 30-minute pilot balloon observations as outlined on page 181 of reference 10. The hourly vertical temperature observations were processed to provide temperature profiles. This information allowed determination of the potential temperature gradients representing atmospheric stability from stack top to an elevation above plume top.

3.3.3 Plume Characteristics

Plume rise data were resolved from the surface photographs by a graticule technique using template overlays specially constructed to coincide with the particular camera lens. This technique is described in detail in reference 1. Information obtained in this manner agrees substantially with the observations made during helicopter flights. Computer-resolved plots of the plume profiles were obtained for each separate plume rise photograph. For each day of sampling a number of consecutive photographs were consolidated into composite observations. The number of photographs used for each composited observation depended on the constancy of the prevailing meteorological conditions.

Made at 5-minute intervals, the 545 separate plume rise photographs taken at Bull Run were consolidated into 73 composite observations. These observations were combined with the 59 composite observations resulting from consolidating the 601 separate plume rise photographs made during the previous study[1].

4.0 DATA EVALUATION

The comprehensive field observations were evaluated to determine the relationship of stack height, plume rise, and atmospheric stability and the relationship of the initial plume rise with effective plume rise.

4.1 Power Plant Operations

For a generalized treatment of plume rise, the temperature difference between stack effluent and ambient air is replaced by the equivalent deficiency of density. Since this deficiency of density creates a buoyancy force, the plume rise observations were examined in accordance with a buoyancy flux parameter which is presented by Briggs[9] as:

$$F = gV_s r^2 \ (\Delta\rho/\rho_a) \qquad (1)$$

4.2 Meteorological Conditions

Wind speed relationships were examined because of the influence of wind speed on plume rise. It was noted that the wind speed at stack top is usually less than the mean value between stack top and plume top, figure 5. The latter was assumed to be more representative of the influential wind speed and is therefore used in evaluating plume rise. The atmospheric stability was also defined as that stability prevalent from top of stack to top of the plume.

4.3 Plume Characteristics

A significant consideration in an evaluation of plume rise is the initial phase of plume rise by virtue of its kinetic and thermal energy. Examination of the plume observations indicated that for most cases the initial rise is that rise observed within the first 152 meters (500 feet) from the stack.

The mean height of top and bottom of the plume was determined as a function of distance from the source for each of the 132 composited observations. Rise of the plume centerline above stack top, shown in table 3 as a function of distance, was defined as the arithmetic mean of the plume top and bottom elevations.

4.4 Relationship of Stack Height, Plume Rise, and Stability

Plume rise observations at the Bull Run 244-meter stack, Paradise 183-meter stack, and the Gallatin 152-meter stack were divided into two ranges of atmospheric stabilities resulting in six sets of observations. The average potential temperature gradient for the six sets of data ranged from 0.0095 °C/100 m at Paradise to 0.94 °C/100 m at Bull Run.

Plume rise information averaged for each set of data, table 4, includes, for 12 downwind intervals of 152 meters each, the (1) number of plume rise photographs, (2) number of composited observations, (3) accumulated relative plume rise, Δh_R, which is expressed as:

$$\Delta h_{R_n} = \Delta h_n / \Delta h_1 \qquad (2)$$

and (4) relative rate of change in plume rise with distance less the initial rise assumed as unity, Δh_X:

$$\Delta h_X = [(\Delta h_{R_n}/\Delta h_{R_{n-1}})-1] \quad (3)$$

A log-log plot of the observed accumulated relative plume rise, Δh_R, with downwind intervals, n, figure 6, indicates, for each data set, a uniform exponential rate of increase in plume rise with distance out to approximately seven downwind intervals (1,064 meters) from the source. Irregularity in the rate of rise beyond this distance is attributed primarily to distortion in the plume photographs for these extended distances. Of the 1,112 photographs of the initial plume rise at 152 meters, only 295 extended beyond 1,064 meters.

The observed relative rate of change in plume rise with distance, Δh_X, up to seven downwind intervals, decreases exponentially with distance for each stack height and stability range, figures 7-9. A least-squares regression line of observed relative rate of change in plume rise values on the downwind intervals is obtained to determine an expression for the straight line which best fits the plot of the relative rate of change in plume rise versus distance for each stack height and stability range--illustrated by the lines in figures 7-9. With this expression, the relative rate of change in plume rise is determined out to the distance where the relative rate of change in rise for a particular downwind interval is 1 percent of that for the preceding interval, tables 5-7, for each stack height and stability class. The accumulated relative rise at this point, table 8, is hereafter referred to as the maximum accumulated relative plume rise.

A plot of the maximum accumulated relative plume rise against the potential temperature gradients for each set of data, figure 10, indicates that the maximum accumulated relative rise is a function of stability, i.e., the less the stability the greater the plume rise, regardless of stack height. Likewise, a plot of downwind distances where the maximum accumulated relative rise occurs with respect to stability, figure 11, indicates that the distance where the maximum accumulated relative rise occurs is a function of the stability regardless of stack height.

4.5 Relationship of Plume Rise and Stability

Since the evaluation of the relationship of stack height, plume rise, and stability indicated that the maximum accumulated relative rise and the relative rate of change of plume rise are not primarily dependent of stack height, the plume rise observations for the three plants were combined and three ranges of potential temperature gradients arbitrarily selected. The three ranges are: (1) $-0.17 < \Delta\theta/\Delta z \leq 0.16$ °C/100 m, (2) $0.16 < \Delta\theta/\Delta z \leq 0.70$ °C/100 m, and (3) $0.70 < \Delta\theta/\Delta z \leq 1.87$ °C/100 m. The average potential temperature gradient for the three sets of data is 0.05, 0.43, and 1.06 °C/100 m, respectively.

Plume rise information averaged for each set of data, table 9, includes, for 12 downwind intervals of 152 meters each, the (1) number of plume rise photographs, (2) number of composited observations, (3) accumulated relative plume rise, Δh_R (equation 2), and (4) relative rate of change in plume rise with distance less the initial rise assumed as unity, Δh_x (equation 3).

A log-log plot of the observed accumulated relative plume rise with downwind intervals, figure 12, indicates for each data set, a uniform exponential rate of increase in plume rise out to approximately seven downwind intervals (1,064 meters) from the stack. Again, the irregularity in the rate of rise beyond this distance is attributed to distortion in the plume photographs.

The observed relative rate of change in plume rise with distance for the seven downwind intervals for each stability range, figure 13, decreases exponentially with distance. These points are used to determine an expression for the straight line which best fits the plot of the change in plume rise versus distance--illustrated for each stability range by the straight lines in figure 13. With this expression, the relative rate of change in plume rise is determined out to the distance where the relative rate of change in rise for a particular downwind interval is 1 percent of that for the preceding interval, table 10. Figure 14 illustrates the fitted curves relating the accumulated relative plume rise to distance, using the regression equations shown in figure 13. The maximum accumulated relative plume rise plotted against the potential temperature gradients for each set of data, figure 15, indicates the maximum accumulated relative rise is a function of atmospheric stability.

4.6 Relationship of Initial Plume Rise and Effective Plume Rise

It has been indicated by the preceding evaluations that the rate of change of plume rise with distance and the point where the maximum accumulated relative rise occurs are dependent on the atmospheric stability. Since both evaluations were relative to the initial plume rise, an initial plume rise model[5,9] was assumed as:

$$\Delta h_1 = K \frac{F^{1/3}}{\bar{u}} \qquad (4)$$

The initial plume rise coefficients, K, are approximately the same for each stability range, i.e.,

$$\Delta h_1 = 43 \frac{F^{1/3}}{\bar{u}} \qquad (5)$$

as shown in table 11 by the nearly constant values for K.

The initial plume rise is primarily a function of the mean wind speed between stack top and plume top and plant operating parameters. Therefore, with the rate of change in plume rise and the distance where this rate reaches a minimal value depending on the atmospheric stability, the effective plume rise is directly related to the initial plume rise.

5.0 RESULTS OF EVALUATION AND RECOMMENDED PROCEDURE

A principal requirement in determining potential surface concentration of stack emissions from large power plants is the procedure for calculating the plume rise where the rate of change in plume rise as a function of distance reaches a minimal value, i.e., the effective plume rise. Relating the accumulated relative plume rise, Δh_R, which is a function of the atmospheric stability, to the initial plume rise, Δh_1, obtains the effective plume rise, Δh, by the relation:

$$\Delta h_n = \Delta h_1 \, \Delta h_R \qquad (6)$$

Using the accumulated relative rise for the near neutral stability group, table 12 ($-0.17 < \Delta\theta/\Delta z \leq 0.16$), average = 0.05 °C/100 m), an expression for estimating the effective plume rise at any downwind distance, x, up to 3,000 meters is determined as:

$$\Delta h_n = 2.50\ x^{0.56}\ F^{1/3}\ \bar{u}^{-1} \qquad (7)$$

For moderately stable conditions, table 12 ($0.16 < \Delta\theta/\Delta z \leq 1.87$, average = 1.06 °C/100 m), for distance, x, up to 1,960 meters:

$$\Delta h_n = 3.75\ x^{0.49}\ F^{1/3}\ \bar{u}^{-1} \qquad (8)$$

Very stable conditions, table 12 ($0.70 < \Delta\theta/\Delta z \leq 1.87$, average = 1.06 °C/100 m), for distance, x, up to 1,960 meters:

$$\Delta h_n = 13.8\ x^{0.26}\ F^{1/3}\ \bar{u}^{-1} \qquad (9)$$

For the above distances indicated for each stability range and for other distances, the effective plume rise for each range may be obtained by the relation shown in equation 6, i.e., multiplying equation 5 by the appropriate Δh_{R_n} value shown in table 12 for different downwind distances.

A plot of the percent of rate of change in plume rise with distance for the projected accumulated relative plume rise for the three data cases is shown in figure 16. For applications to TVA power plants, the minimal change in plume rise with distance was selected at 1,824 meters (12 intervals of distance on figure 16). At this distance the rate of change of plume rise was approximately 4 percent for the 0.05 °C/100 m and 0.43 °C/100 m groups and 1 percent for the 1.06 °C/100 m group.

The accumulated relative rise at 1,824 meters for the three stability ranges is indicated by the points on figure 17. An expression for the straight line that best fits a semilog plot of these values of accumulated relative plume rise versus the potential temperature gradient (shown by the solid line in figure 17) is determined as:

$$\Delta h_{R_n} = 4.02 \exp\left(-0.64 \frac{\Delta\theta}{\Delta z}\right) \qquad (10)$$

Substituting in equation 6 obtains the effective plume rise at 1,824 meters for any potential temperature gradient by:

$$\Delta h_n = 173 \frac{F^{1/3}}{\bar{u} \exp\left(0.64 \frac{\Delta\theta}{\Delta z}\right)} \qquad (11)$$

or for neutral conditions, i.e., $\Delta\theta/\Delta z = 0$:

$$\Delta h_n = 173 \frac{F^{1/3}}{\bar{u}} \qquad (12)$$

6.0 CONCLUSIONS AND RECOMMENDED FURTHER STUDIES

It has been demonstrated in this evaluation of plume rise observations for single stack operations at TVA power plants that the rate of plume rise with downwind distance depends on the atmospheric stability. However, the effective plume rise depends on the initial rise which is a function of the stack design and emission parameters and mean wind speed between stack top and plume top. Therefore, for a known stability class, one can estimate the effective plume rise for any downwind distance. However, if a downwind distance where the effective rise occurs is selected, an expression for estimating the effective plume rise during any stability condition may be determined.

It has also been indicated that stack height affects the effective plume rise only because of the possibility of releasing the stack effluent into different meteorological regimes since the meteorological parameters are defined from stack top to plume top.

It is recommended that the results of this evaluation be analyzed further by incorporating plume rise observations at the TVA Cumberland power plant which will begin operating in the near future. This plant will have two 1,275-mw units with ~~one~~ two 305-meter (1,000 feet) stacks. It is also recommended that this evaluation be examined with respect to moisture-laden plumes such as cooling tower emissions and emissions from power plants using scrubbing techniques for reduction of SO_2 in the stack effluents.

Results of these extended studies will be important in design and site considerations for power plants constructed in the future and for modifications to presently operating power plants. These considerations and modifications, generated by the increasing concern for preserving environmental quality, could include cooling towers for control of thermal pollution or wet scrubbers for reduction of air pollution.

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8.0 NOMENCLATURE

$F = gV_s r^2 (\Delta\rho/\rho_a)$ = buoyancy flux parameter ($m^4\ sec^{-1}$)

g = acceleration due to gravity ($m\ sec^{-2}$)

Δh = effective plume rise (m)

Δh_1 = observed initial plume rise (m)

Δh_n = observed plume rise at interval n, n = 1-12 (m)

Δh_{R_n} = accumulated relative plume rise at interval n, n = 1-12 (dimensionless)

Δh_x = relative rate of change in plume rise (dimensionless)

K = coefficient related to initial plume rise ($m^{2/3}$)

r = inside radius of stack (m)

$\bar{u}$ = mean wind speed between stack top and plume top ($m\ sec^{-1}$)

V_s = stack gas exit velocity ($m\ sec^{-1}$)

x = horizontal distance downwind of stack (m)

$\Delta\rho = \rho_a - \rho_s$ ($gm\ m^{-3}$)

ρ_a = density of ambient air at stack top ($gm\ m^{-3}$)

ρ_s = density of stack gas at stack top ($gm\ m^{-3}$)

$\frac{\Delta\theta}{\Delta z}$ = potential temperature gradient (°C/100 m)

TENNESSEE VALLEY AUTHORITY
Division of Environmental Research and Development

APPENDIX A

TABLES

Muscle Shoals, Alabama
October 1971

Table 1

PLANT DESIGN AND OPERATIONAL DATA

	Paradise	Gallatin	Bull Run
Number of Units	3	4	1
Rated Plant Capacity	2,558	1,255	950
Stack Number	3	2	1
Height (meters)	2-183, 1-244	152	244
Inside Diameter (meters)	8	8	9
Temperature of Flue Gas Leaving Stack (°C)	140.0	136.7	137.9

Table 2

METEOROLOGICAL AND EMISSION PARAMETERS FOR ESTIMATING PLUME RISE

Power Plant	Composite Obs. No.	No. of Photographs	Potential Temperature Gradient (°C/100 m)	V_s (m/sec)	u_1 (m/sec)	$\bar{u}$ (m/sec)	ρ_s (gm/m^3)	ρ_a (gm/m^3)	Δh_1 (meters)
Paradise	1	9	1.73	15.6	4.8	8.5	0.05976	0.07588	32
	2	8	-0.05	15.6	5.5	6.8	0.06054	0.07405	50
	3	9	-0.09	15.6	4.7	4.9	0.06054	0.07405	93
	4	4	1.37	16.4	7.9	8.1	0.05999	0.07418	44
	5	4	0.85	16.4	4.8	6.0	0.05999	0.07418	80
	6	5	0.00	16.4	2.3	2.6	0.00000	0.00000	160
	7	10	0.01	16.4	5.3	4.7	0.05999	0.07418	104
	8	3	0.44	17.8	5.4	4.1	0.05965	0.07489	77
	9	8	0.17	17.8	2.7	3.3	0.05965	0.07489	145
	10	14	0.01	17.8	3.5	1.9	0.05965	0.07489	168
	11	5	0.59	17.1	4.3	4.5	0.05879	0.07575	107
	12	5	0.65	17.1	2.7	3.7	0.05879	0.07575	124
	13	3	0.30	17.1	1.6	3.4	0.05879	0.07575	240
	21	8	-0.17	15.3	5.1	7.3	0.05876	0.07503	54
	22	10	0.28	15.6	4.8	7.7	0.05960	0.07418	62
	23	10	-0.04	15.6	9.9	10.9	0.05960	0.07418	44
	24	6	-0.13	15.6	6.9	7.2	0.05960	0.07418	29
	25	15	0.18	15.6	11.3	11.4	0.05960	0.07418	26
	26	6	0.01	18.0	10.3	10.8	0.05627	0.07891	43
	27	10	0.00	18.0	10.2	9.5	0.05627	0.07891	43
	28	8	0.02	18.0	9.8	10.0	0.05607	0.07891	50
	29	8	-0.02	18.0	7.4	8.3	0.05627	0.07891	41
	30	12	0.08	16.4	6.9	5.2	0.05750	0.07692	74
	1	10	-0.02	16.4	5.9	5.7	0.05750	0.07692	94
	38	17	1.12	19.1	10.7	16.8	0.05640	0.07736	30
	39	13	0.37	19.1	9.6	13.8	0.05640	0.07737	34
	40	14	0.02	19.1	8.2	10.6	0.05640	0.07737	26
	41	17	0.09	19.1	8.2	8.4	0.05640	0.07737	40
	42	11	0.27	19.2	5.2	8.0	0.05498	0.07891	62
	43	17	0.11	19.2	4.6	5.2	0.05498	0.07891	87

TABLE 2 (CONTINUED)

Power Plant	Composite Obs. No.	No. of Photographs	Potential Temperature Gradient (°C/100 m)	V_s (m/sec)	$\bar{u}_1$ (m/sec)	$\bar{u}$ (m/sec)	ρ_{s_3} (gm/m^3)	ρ_{a_3} (gm/m^3)	Δh_1 (meters)
Gallatin	3	2	0.63	15.4	3.7	2.8	0.06147	0.07296	41
	4	2	0.41	15.4	2.9	2.5	0.06104	0.07364	43
	6	2	0.72	16.1	3.8	5.9	0.06060	0.07405	26
	7	2	0.22	16.1	4.8	5.0	0.06060	0.07405	32
	8	2	0.11	16.1	5.2	5.8	0.06060	0.07405	31
	9	14	0.39	16.4	2.5	5.4	0.06053	0.07405	34
	10	9	0.30	15.4	5.8	6.9	0.06191	0.07256	31
	11	8	-0.16	15.4	6.5	6.9	0.06191	0.07256	119
	12	13	-0.03	15.3	3.8	3.8	0.06189	0.07282	93
	13	7	0.09	15.3	2.4	2.2	0.06189	0.07282	192
	14	22	0.23	15.3	2.6	2.1	0.06189	0.07282	117
	15	4	0.30	15.3	2.8	2.1	0.06189	0.07282	430
	16	12	0.74	15.6	2.8	5.1	0.06149	0.07336	76
	17	22	0.44	15.6	1.8	2.9	0.06149	0.07336	109
	18	31	-0.02	15.6	5.3	6.1	0.06149	0.07336	62
	19	13	0.68	15.5	3.3	5.0	0.06100	0.07350	68
	20	37	-0.04	15.5	4.6	5.8	0.06100	0.07350	76
	21	21	1.06	15.3	1.7	4.6	0.06193	0.07269	67
	22	13	0.97	15.3	1.6	3.2	0.06193	0.07269	124
	23	7	0.36	15.3	2.7	2.5	0.06193	0.07269	150
	24	15	0.61	14.8	2.8	5.2	0.05932	0.07633	127
	25	10	0.10	14.8	4.1	4.6	0.05932	0.07633	66
	26	17	0.00	14.8	8.2	9.9	0.05932	0.07633	45
	27	6	0.13	14.8	6.7	10.4	0.05932	0.07633	46
	28	4	0.06	15.2	2.7	3.1	0.05571	0.07844	63
	29	20	0.00	15.2	4.8	4.4	0.05771	0.07844	74
	30	4	-0.15	15.2	3.3	3.7	0.05771	0.07860	59
	31	5	-0.08	15.2	1.3	1.7	0.05771	0.07860	104
Bull Run	1	8	0.66	19.1	1.6	3.1	0.05993	0.07447	274.9
	2	8	0.82	19.0	1.8	3.2	0.06022	0.07410	274.0
	3	11	0.19	18.9	3.2	3.2	0.06063	0.07361	188.2
	4	16	1.38	19.9	4.4	8.5	0.05942	0.07532	77.5
	5	6	0.59	10.1	8.7	9.5	0.06006	0.09550	61.7

TABLE 2 (CONTINUED)

Power Plant	Composite Obs. No.	No. of Photographs	Potential Temperature Gradient (°C/100 m)	V_s (m/sec)	u_1 (m/sec)	$\bar{u}$ (m/sec)	ρ_s (gm/m^3)	ρ_a (gm/m^3)	Δh_1 (meters)
Bull Run (cont'd)	6	7	0.48	10.2	8.6	8.8	0.05975	0.07589	53.8
	7	6	0.38	10.2	8.4	9.2	0.05976	0.07588	45.3
	8	4	0.37	10.2	6.6	7.7	0.05979	0.07585	46.5
	9	5	0.27	10.2	5.6	6.9	0.05981	0.07582	61.4
	10	4	0.24	10.2	8.7	5.9	0.05981	0.07582	58.7
	11	7	1.36	19.0	6.8	6.7	0.05938	0.07680	95.8
	12	6	1.36	19.0	6.3	6.4	0.05938	0.07680	93.0
	13	6	1.24	18.9	5.8	6.5	0.05959	0.07654	94.9
	14	6	1.12	18.9	4.3	6.3	0.05969	0.07641	90.0
	15	6	0.96	18.9	4.6	6.2	0.05979	0.07627	98.2
	16	8	0.16	20.5	4.3	5.5	0.05992	0.07611	128.0
	17	5	0.61	18.8	3.1	5.0	0.06002	0.07597	140.2
	18	5	0.55	18.7	4.3	4.6	0.06013	0.07585	138.7
	19	6	1.16	18.9	1.6	3.1	0.06014	0.07624	207.6
	20	6	1.16	18.9	1.2	3.0	0.06014	0.07624	219.2
	21	7	1.17	18.9	2.0	4.5	0.06016	0.07621	207.0
	22	6	1.20	18.9	1.2	4.6	0.06016	0.07621	156.3
	23	6	1.09	18.9	1.8	5.1	0.06021	0.07615	141.0
	24	7	0.89	18.9	1.9	5.3	0.06032	0.07600	140.2
	25	7	0.63	18.8	1.8	4.1	0.06045	0.07585	169.7
	26	6	0.48	18.7	2.4	4.2	0.06073	0.07550	142.3
	27	8	1.15	19.3	1.3	3.4	0.06094	0.07576	189.7
	28	8	0.88	19.3	1.1	2.7	0.06118	0.07545	242.3
	29	5	0.90	19.3	1.1	2.2	0.06072	0.07562	377.0
	30	5	0.68	19.2	.6	2.0	0.06100	0.07527	394.4
	31	7	0.58	19.2	.5	2.1	0.06112	0.07511	384.3
	32	10	0.94	19.6	3.1	2.9	0.06028	0.07538	294.3
	33	7	0.83	19.6	3.1	2.0	0.06021	0.07562	422.4
	34	10	1.23	23.8	5.0	3.4	0.05995	0.07542	99.1
	35	9	0.84	23.7	3.7	3.1	0.06026	0.07504	156.6
	36	8	0.89	19.2	3.3	3.7	0.05862	0.07770	150.8

TABLE 2 (CONTINUED)

Power Plant	Composite Obs. No.	No. of Photographs	Potential Temperature Gradient (°C/100 m)	V_s (m/sec)	$\bar{u}_1$ (m/sec)	$\bar{u}$ (m/sec)	ρ_s (gm/m^3)	ρ_a (gm/m^3)	Δh_1 (meters)
Bull Run (cont'd)	37	7	0.93	19.3	2.9	2.9	0.05857	0.07776	258.5
	38	6	0.58	19.4	2.3	6.0	0.06014	0.07572	132.7
	39	8	0.69	19.4	1.4	5.4	0.06014	0.07572	155.9
	40	7	0.54	19.3	.9	3.5	0.06042	0.07537	236.0
	41	9	0.52	19.3	1.1	2.9	0.06045	0.07532	308.3
	42	9	0.11	20.0	9.9	8.2	0.05895	0.07694	88.8
	43	10	0.11	19.8	6.9	8.5	0.05922	0.07658	42.0
	44	5	0.16	20.5	5.5	5.4	0.05823	0.07830	106.7
	45	10	0.16	20.5	5.2	6.6	0.05823	0.07830	111.3
	46	7	0.21	20.6	3.1	5.8	0.05820	0.07834	105.8
	47	5	0.06	20.4	2.1	2.9	0.05861	0.07780	114.6
	48	8	0.12	20.3	3.7	5.2	0.05894	0.07736	196.1
	49	10	0.15	20.2	3.8	4.0	0.05909	0.07715	258.2
	50	9	1.12	20.3	1.7	4.5	0.05801	0.07838	147.2
	51	9	0.77	20.3	2.0	5.6	0.05827	0.07804	135.9
	52	9	0.77	20.3	4.0	5.3	0.05857	0.07773	155.3
	53	6	1.87	7.8	4.3	2.9	0.06064	0.07707	38.9
	54	7	1.68	7.8	3.9	3.4	0.06087	0.07677	28.2
	55	7	1.25	7.8	3.7	3.9	0.06109	0.07648	27.4
	56	6	0.86	7.9	2.1	2.2	0.06130	0.07633	82.7
	57	6	0.82	7.9	.7	1.3	0.06154	0.07603	194.6
	58	10	0.26	8.0	1.5	0.8	0.06252	0.07474	547.5
	59	11	0.45	14.3	1.2	1.5	0.06175	0.07474	233.7
	60	5	0.39	14.3	1.3	1.4	0.06188	0.07460	0.0
	61	9	0.86	14.1	2.2	1.6	0.06046	0.07531	300.2
	62	6	1.25	17.1	5.1	4.5	0.06018	0.07517	22.8
	63	7	1.00	17.0	4.9	2.9	0.06008	0.07531	35.5
	64	7	0.81	17.1	4.5	3.0	0.06022	0.07517	50.5
	65	7	0.91	13.3	1.9	1.7	0.05867	0.07768	145.8
	66	4	0.90	13.4	1.3	1.5	0.05877	0.07752	259.9
	67	11	0.72	14.0	1.5	3.9	0.06016	0.07575	48.3
	68	10	0.63	13.7	1.5	3.9	0.06049	0.07517	33.5
	69	9	0.48	13.7	2.1	3.8	0.06051	0.07517	43.1
	70	3	0.15	13.9	5.2	7.3	0.05895	0.07692	23.2

TABLE 2 (CONTINUED)

Power Plant	Composite Obs. No.	No. of Photographs	Potential Temperature Gradient (°C/100 m)	V_s (m/sec)	$\bar{u}_1$ (m/sec)	$\bar{u}$ (m/sec)	ρ_s (gm/m^3)	ρ_a (gm/m^3)	Δh_1 (meters)
Bull Run (cont'd)	71	8	0.08	13.9	6.8	8.6	0.05905	0.07677	10.6
	72	6	0.02	14.0	5.0	4.6	0.05833	0.07813	30.0
	73	8	0.05	14.0	3.4	3.7	0.05836	0.07813	40.3
	74	10	0.15	14.0	4.1	5.3	0.05840	0.07813	35.3

Table 3

PLUME RISE ABOVE STACK TOP WITH DISTANCE FROM PLANT

Power Plant	Obs. No.	Potential Temperature Gradient (°C/100 m)	x =	Plume Rise (meters) at Distance Downwind, x (meters)												
				0	76	152	305	457	610	762	914	1,067	1,219	1,371	1,523	1,675
Paradise	1	1.73		20.0	31.6	45.7	43.7	48.9	61.4	73.5	85.7	88.7	100.0	110.9		
	2	-0.05		31.3	50.2	67.2	71.2	94.9	118.6	142.6	166.3	178.5	200.7	222.9		
	3	-0.09		59.0	92.4	108.9	109.5	146.9	183.7	220.2	256.9					
	4	1.37		31.3	44.0	66.2	83.6	95.3	99.7	97.6	103.3	114.9	121.3	124.3	126.1	126.8
	5	0.85		58.9	80.2	111.2	138.3	152.9	164.8	172.7	181.2	187.6	192.1	186.5	187.6	189.4
	6			96.4	159.6	227.7	268.8	303.5	326.0	339.0	353.0	373.7	392.9	442.7	501.7	496.2
	7	0.01		57.1	103.6	159.6	184.8	190.0	194.3	192.1	182.4	187.0				
	8	0.44		47.4	76.3	125.2	166.0	202.0	229.8	253.9	274.2	294.6	314.1	329.6		
	9	0.17		92.1	144.4	202.2	216.5	249.0	282.1	312.2	377.5	362.4	387.3	413.2	434.5	
	10	0.01		117.6	167.2	259.9	301.3	306.2	329.9	322.0	329.3	305.9				
	11	0.59		65.9	107.0	169.0	213.4	246.9	272.7	291.3	308.3	328.4	354.5			
	12	0.65		80.2	123.4	174.5	213.4	246.9	276.4	306.5	332.9	362.2	387.4	406.9		
	13	0.30		177.2	239.3	311.6	357.2	392.8	416.2	432.4	445.7	456.1	456.1	453.9	453.9	457.0
	21	-0.17		34.4	53.5	77.5	102.2	125.6	147.8	166.9	187.9	241.4	263.9	268.5	287.9	307.4
	22	0.28		32.8	61.7	91.5	114.9	139.6	158.7	181.5	200.0	218.3	232.6	236.9	262.1	
	23	-0.04		24.9	43.5	64.8	83.3	112.2	114.9	132.3	153.9	176.4	177.3	198.6		
	24	-0.13		16.1	29.2	49.9	75.4	96.0	110.4	121.9	139.0	145.0	156.3			
	25	0.18		12.8	25.5	47.1	62.3	70.2	84.5	92.4	105.2	134.4	145.0	190.4		
	26	0.01		25.5	42.9	62.6	77.5	93.0	110.0	106.1						
	27			24.9	42.9	62.3	67.2	89.0	106.4	103.0	107.3					
	28	0.02		33.4	49.6	60.8	64.2	76.6	86.0	94.3		-				
	29	-0.02		26.4	40.4	53.8	60.2	68.7	87.9	101.6	108.2	97.6				
	30	0.08		43.5	74.2	119.2	165.7	193.0	226.5	259.4	288.0	306.8	381.9			
	31	-0.02		59.0	94.0	116.5	131.7	153.3	151.4	159.6	170.3	177.3	208.8	217.7		
	38	1.12		16.4	30.1	47.7	62.3	76.6	90.3	103.4	113.7	123.4	137.4	162.0	179.1	191.2
	39	0.37		18.2	33.4	54.7	74.2	94.6	112.2	124.7	138.7	149.3	158.4	167.9	179.4	204.0
	40	0.02		14.0	25.8	51.4	83.9	101.6	115.2	134.0	157.5	164.8	178.8	198.9	211.3	225.0
	41	0.09		26.5	39.8	51.0	66.0	86.0	113.1	130.5	142.9	153.9	164.8	211.3		
	42	0.27		36.8	62.3	87.6	106.1	132.3	153.9	174.2	190.0					
	43	0.11		52.6	87.0	120.4	136.8	141.0	164.8	181.5						
Gallatin	3	0.63		20.1	40.5	80.8	121.3	161.5	202.1	239.3	275.5	311.5	347.5	383.8		
	4	0.41		21.6	43.3	86.6	129.8	173.1	216.4	248.4	275.8	303.3	330.7	358.1	373.7	374.3
	6	0.72		13.1	25.9	51.8	78.0	103.9	129.8	144.5	154.5	164.6	174.7	184.7	191.8	194.8
	7	0.22		15.8	31.7	63.4	95.1	127.1	158.8	178.0	192.3	207.0	221.3	235.6		

TABLE 3 (CONTINUED)

Power Plant	Obs. No.	Potential Temperature Gradient (°C/100 m)	x =	Plume Rise (meters) at Distance Downwind, x (meters)												
				0	76	152	305	457	610	762	914	1,067	1,219	1,371	1,523	1,675
Gallatin (cont'd)	8	0.11		15.5	31.4	62.5	93.9	125.2	156.3	182.9	199.3	14.9	218.8	222.5	252.4	254.5
	9	0.39		17.1	34.4	68.9	103.3	137.8	172.2	188.7	198.4	207.9	217.3	227.1		
	10	0.30		15.5	31.1	61.9	93.0	123.7	154.8	166.7	173.4	180.1	186.8	193.2		
	11	-0.16		9.1	18.5	36.8	55.3	73.9	92.4	110.7	129.2					
	12	-0.03		59.1	92.7	127.1	159.3	175.4	213.8							
	13	0.09		124.1	192.3	322.2	382.2	413.9	444.4	417.0	459.6	449.9	405.1	429.8	454.5	
	14	0.23		71.9	116.7	171.3	223.7	285.0	334.7	385.6	463.6	554.7				
	15	0.30		450.8	430.4											
	16	0.74		48.8	76.2	131.7	174.7	184.4	194.5	208.2	215.5	226.2	229.2	233.5	244.8	253.0
	17	0.44		70.4	108.8	185.3	237.7	247.8	259.1	265.8	316.7	300.2	310.3			
	18	-0.02		37.4	61.4	109.2	156.6	195.2	219.2	250.2	275.5	313.5	333.9	351.5	379.5	378.9
	19	0.68		43.3	68.0	118.0	160.6	167.9	180.7	193.5	210.0	220.1	187.1	192.3		
	20	-0.04		45.9	75.4	134.4	193.4	250.3	284.9	319.9	329.0	353.3	387.9			
	21	1.06		46.2	67.2	109.1	141.3	155.6	162.6	172.9	167.8	170.2	166.0	152.3	195.5	
	22	0.97		95.4	124.4	182.3	234.1	248.7	250.9	242.6	234.7	227.7	233.5			
	23	0.36		111.0	149.9	227.5	299.6	220.6	346.7	321.4	286.4	269.7				
	24	0.61		80.9	126.5	182.4	219.2	249.6	273.0	309.6	334.5	357.9	374.9	395.5	411.0	461.6
	25	0.10		42.9	65.4	89.4	127.7	170.9	191.3	226.2	246.9	258.5	281.6			
	26			24.0	44.4	62.6	80.6	99.1	97.3	108.2	108.9	136.5	165.7	185.5	225.3	250.9
	27	0.13		26.2	45.6	71.8	90.9	103.0	108.3	142.6	164.8					
	28	0.06		46.5	62.9	82.4	112.0	134.4	165.7	195.2	219.9	249.3	276.1	201.0	294.3	
	29			58.4	74.2	110.7	141.4	170.3	197.0	227.1	249.9	262.6	273.5	294.9	309.2	305.6
	30	-0.15		48.3	59.0	80.9	80.9	100.3	119.8							
	31	-0.08		76.3	103.7	135.9	162.4	172.7								
Bull Run	1	0.66		140.5	220.1	274.9	304.7	318.0	322.0	318.4	308.9					
	2	0.82		134.0	204.9	274.0	307.1	322.6	326.6	326.3	325.0					
	3	0.19		75.1	123.4	188.2	243.9	288.9	303.2	340.6	371.6					
	4	1.38		31.6	52.6	77.5	96.4	105.5	115.2	119.1	127.4	135.0	142.0			
	5	0.59		17.6	34.0	61.7	87.3	110.0	132.0	148.7	164.0					
	6	0.48		15.8	30.4	53.8	74.8	93.6	111.0	123.1	128.3					
	7	0.38		14.9	27.4	45.3	62.6	76.0	87.6	97.6	107.0					
	8	0.37		14.9	28.0	46.5	60.8	70.8	82.4	91.2	102.8					
	9	0.27		19.8	38.0	61.4	83.3	109.2	137.1	155.7	170.0					

TABLE 3 (CONTINUED)

Power Plant	Obs. No.	Potential Temperature Gradient (°C/100 m)	x =	Plume Rise (meters) at Distance Downwind, x (meters)												
				0	76	152	305	457	610	762	914	1,067	1,219	1,371	1,523	1,675
Bull Run (cont'd)	10	0.24		21.3	41.3	58.7	76.6	105.2	133.8	153.2	165.7					
	11	1.36		37.4	59.3	95.8	122.5	144.1	159.3	169.0	172.7					
	12	1.36		37.4	59.6	93.0	120.1	139.9	154.2	163.6	168.8					
	13	1.24		39.5	62.9	94.9	121.0	140.5	154.8	163.3	171.5					
	14	1.12		39.5	59.9	90.9	117.4	139.6	152.3	159.0	161.2					
	15	0.96		43.8	66.6	98.2	121.9	139.9	147.2	149.3	150.8					
	16	0.16		59.9	89.4	128.0	154.8	174.8	190.0	196.7	196.4					
	17	0.61		59.4	91.8	140.2	181.4	213.2	225.9	234.1	248.3					
	18	0.55		65.0	99.4	138.7	155.0	157.8	171.5	197.0	223.8					
	19	1.16		119.8	161.8	207.6	232.6	246.6	254.2	256.9	257.2					
	20	1.16		125.5	171.5	219.2	242.9	256.6	264.5	269.1	268.5					
	21	1.17		122.8	163.6	207.0	227.4	241.7	250.9	254.7	255.1	253.6				
	22	1.20		96.0	127.1	156.3	173.6	185.2	193.4	199.8	203.1	204.9				
	23	1.09		82.4	109.2	141.0	163.9	180.3	192.2	199.2	203.4					
	24	0.89		78.1	105.3	140.2	166.0	185.5	201.0	212.8	220.8					
	25	0.63		93.3	129.2	169.7	196.7	215.0	229.0	240.2	249.0					
	26	0.48		87.9	118.0	142.3	159.6	173.9	188.8	203.1	216.0	225.6				
	27	1.15		107.0	149.9	189.7	213.2	226.2	235.3	240.2	240.5	288.9	288.9	288.9	293.7	
	28	0.88		137.1	193.3	242.3	257.8	257.2	251.8	244.1	233.5	222.0				
	29	0.90		239.9	303.5	377.0	406.5	423.8	434.5	443.0	450.6	491.4				
	30	0.68		253.9	326.9	394.4	423.0	436.0	446.4	454.1						
	31	0.58		269.7	334.3	384.3	412.0	431.2	446.0	456.4						
	32	0.94		225.3	265.8	294.3	298.3	296.2	293.7	290.7	290.7	305.9				
	33	0.83		310.8	365.6	422.4	452.8	464.0	472.5	478.6	487.4	532.1				
	34	1.23		32.8	56.5	99.1	134.7	154.5	175.1	165.1	180.9					
	35	0.84		61.1	106.1	156.6	195.2	222.0	233.8	241.4	240.8	244.5	222.2			
	36	0.89		59.0	100.3	150.8	187.3	209.5	223.0	236.6	243.6	200.7	208.9			
	37	0.93		88.4	153.3	258.5	320.7	349.9	369.7	389.5	424.9	462.1	484.9	516.9	615.7	
	38	0.58		64.5	100.9	132.7	151.4	160.5	165.4	166.0	163.9	161.8	220.1	292.8		
	39	0.69		86.3	125.3	155.9	157.5	170.3	205.9	194.6	191.6					
	40	0.54		156.3	192.5	236.0	262.4	286.1	313.8	327.8						
	41	0.52		219.8	267.3	308.3	329.3	342.7	354.2	360.0						
	42	0.11		33.7	53.2	88.8	137.7	130.7	182.1	208.9						
	43	0.11		19.5	29.2	42.0	66.3	89.0	108.5	135.3						

TABLE 3 (CONTINUED)

Power Plant	Obs. No.	Potential Temperature Gradient (°C/100 m)	x =	Plume Rise (meters) at Distance Downwind, x (meters)												
				0	76	152	305	457	610	762	914	1,067	1,219	1,371	1,523	1,675
Bull Run (cont'd)	44	0.16		50.5	76.9	106.7	131.6	143.5	185.9	186.4						
	45	0.16		50.2	79.4	111.3	128.3	130.7	149.3	189.7	248.1					
	46	0.21		38.9	66.3	105.8	145.6	180.0	229.2	266.7	297.0					
	47	0.06		37.4	62.3	114.6	179.4	230.8	219.2	310.8	426.0					
	48	0.12		86.7	140.4	196.1	241.2	291.6	318.4	362.9	219.4					
	49	0.15		103.4	165.7	258.2	303.2	383.7	357.3	304.4						
	50	1.12		81.5	121.6	147.2	158.4	160.5	162.7	160.2	155.7					
	51	0.77		70.5	108.5	135.9	151.7	160.5	167.2	171.2	173.6	175.7				
	52	0.77		77.6	120.1	155.3	173.2	182.5	188.0	190.4	191.1					
	53	1.87		13.9	23.2	38.9	49.4	56.6	63.1	68.2						
	54	1.68		11.7	18.9	28.2	33.1	33.8								
	55	1.25		12.6	19.5	27.4	31.8	32.6	30.7							
	56	0.86		40.2	61.8	82.7	87.8	81.6								
	57	0.82		119.8	164.6	194.6										
	58	0.26		264.0	368.1	547.5	637.8	687.3								
	59	0.45		110.7	159.3	233.7	244.0	253.8								
	60	0.39		186.4	284.8											
	61	0.86		211.5	253.6	300.2	324.8	337.6	341.8	340.2	345.8	340.0	326.3			
	62	1.25		7.9	13.7	22.8	28.0	30.1								
	63	1.00		12.1	20.6	35.5	47.1	54.9	57.9	68.4						
	64	0.81		16.7	29.3	50.5	67.8	80.4	90.2							
	65	0.91		64.9	103.6	145.8	165.0	171.6	172.1	171.6	174.3	174.3				
	66	0.90		161.5	226.2	259.9	265.0	253.0	245.5	243.2	240.6					
	67	0.72		29.0	40.8	48.3	52.6	57.2								
	68	0.63		17.7	25.7	33.5	39.2	44.8	52.7							
	69	0.48		23.3	33.0	43.1	48.3	52.2								
	70	0.15		7.1	13.2	23.2	32.8	42.3	50.6	56.7						
	71	0.08		4.2	6.6	10.6	17.5	22.8	21.2	20.1						
	72	0.02		10.3	17.4	30.0	44.4									
	73	0.05		13.6	22.3	40.3	57.3	49.4								
	74	0.15		13.0	21.2	35.3	52.3	63.9	72.6	44.2						

Table 4

AVERAGE PLUME RISE DATA WITH TWO STABILITY GROUPS FOR EACH STACK HEIGHT

Power Plant	Stack Ht. (m)	Avg. Potential Temp. Gradient (°C/100 m)	Type of Data	Intervals of Distance (152 meters)											
				1	2	3	4	5	6	7	8	9	10	11	12
Bull Run	244	0.94	1	358	352	338	323	275	255	223	69	19	5	2	
			2	49	49	48	48	44	41	35	15	7	3	2	
			3	1.0000	1.3193	1.5175	1.6438	1.7483	1.8049	1.8569	1.9141	2.0501	2.4550	2.8024	
			4		0.3193	0.1502	0.0832	0.0636	0.0324	0.0288	0.0307	0.0711	0.1975	0.1415	
Bull Run	244	0.23	1	187	172	153	110	89	83	60	6				
			2	25	24	24	23	19	19	12	1				
			3	1.0000	1.5028	1.9435	2.2815	2.6615	2.9746	3.1629	3.2940				
			4		0.5028	0.2933	0.1739	0.1666	0.1176	0.0633	0.0414				
Paradise	183	0.47	1	54	54	54	54	54	53	44	39	31	20	12	11
			2	8	8	8	8	8	8	8	7	7	6	4	3
			3	1.0000	1.4589	1.8173	2.1470	2.4117	2.6395	2.8445	3.0293	3.1183	3.2752	3.4557	3.6975
			4		0.4589	0.2457	0.1814	0.1233	0.0945	0.0777	0.0650	0.0525	0.0273	0.0511	0.0700
Paradise	183	0.0095	1	189	177	168	150	132	102	79	52	38	25	13	9
			2	19	19	19	19	19	19	16	14	11	9	4	3
			3	1.0000	1.4415	1.7465	2.0797	2.3839	2.6127	2.8877	3.1447	3.4813	3.9864	4.2995	4.5290
			4		0.4415	0.2116	0.1908	0.1463	0.0935	0.1053	0.0890	0.1070	0.1451	0.0785	0.0534
Gallatin	152	0.77	1	78	78	78	76	74	70	68	52	41	27	14	9
			2	7	7	7	7	7	7	7	7	7	6	4	3
			3	1.0000	1.6220	2.1329	2.3965	2.6265	2.8537	3.0067	3.1659	3.2076	3.3326	3.6137	3.9526
			4		0.6220	0.3150	0.1236	0.0960	0.0865	0.0536	0.0529	0.0132	0.0890	0.0843	0.0882
Gallatin	152	0.12	1	246	241	230	212	179	148	115	77	54	45	17	11
			2	21	20	20	20	19	17	17	15	13	10	7	5
			3	1.0000	1.5582	2.0613	2.4514	2.8584	3.2123	3.4952	3.5160	4.0604	4.2140	4.7576	4.9168
			4		0.5582	0.3229	0.1892	0.1660	0.1238	0.0881	0.0060	0.1548	0.0378	0.1290	0.0335

1. No. of Photographs.
2. No. of Composited Observations.
3. Accumulated Relative Plume Rise.
4. Relative Rate of Change of Plume Rise.

Table 5

ACCUMULATED RELATIVE PLUME RISE - PARADISE POWER PLANT

183-METER STACK

Distance Intervals (152 m)	Average Potential Temperature Gradient = 0.0095° C/100 m		Average Potential Temperature Gradient = 0.47° C/100 m	
	$\left({}^{1}h_x + 1\right)$ (Dimensionless)	$^{2}\left[\left(\Delta h_{Rn-1}\right)\left(\Delta h_x + 1\right)\right]$ (Dimensionless)	$\left({}^{1}h_x + 1\right)$ (Dimensionless)	$^{2}\left[\left(\Delta h_{R_{n-1}}\right)\left(\Delta h_x + 1\right)\right]$ (Dimensionless)
1	1.0000	1.0000	1.0000	1.0000
2	1.4072	1.4072	1.4555	1.4555
3	1.2510	1.7605	1.2566	1.8290
4	1.1781	2.0739	1.1708	2.1414
5	1.1364	2.3569	1.1245	2.4080
6	1.1098	2.6156	1.0962	2.6397
7	1.0913	2.8545	1.0774	2.8439
8	1.0779	3.0767	1.0640	3.0260
9	1.0677	3.2849	1.0542	3.1900
10	1.0597	3.4809	1.0467	3.3390
11	1.0532	3.6662	1.0408	3.4752
12	1.0480	3.8422	1.0361	3.6005
13	1.0436	4.0098	1.0322	3.7165
14	1.0399	4.1699	1.0290	3.8243
15	1.0368	4.3232	1.0263	3.9249
16	1.0340	4.4704	1.0240	4.0191
17	1.0317	4.6120	1.0220	4.1077
18	1.0296	4.7484	1.0203	4.1912
19	1.0277	4.8801	1.0188	4.2700
20	1.0261	5.0074	1.0175	4.3448
21	1.0246	5.1307	1.0163	4.4158
22	1.0233	5.2501	1.0153	4.4833
23	1.0221	5.3661	1.0144	4.5477
24	1.0210	5.4787	1.0135	4.6092
25	1.0200	5.5882	1.0128	4.6681
26	1.0191	5.6948	1.0121	4.7245
27	1.0182	5.7986	1.0144	4.7785
28	1.0175	5.8999	1.0109	4.8305
29	1.0167	5.9987	1.0103	4.8805
30	1.0161	6.0951		
31	1.0155	6.1894		
32	1.0149	6.2815		
33	1.0144	6.3717		
34	1.0138	6.4599		

1. $\left(h_x + 1\right)$-Relative rate of change of plume rise plus initial rise assumed as unity.
2. $\left[\left(\Delta h_{R_{n-1}}\right)\left(\Delta h_x + 1\right)\right]$--Accumulated relative rise.

TABLE 5 (CONTINUED)

Distance Intervals (152 m)	Average Potential Temperature Gradient = 0.0095° C/100 m		Average Potential Temperature Gradient = 0.47° C/100 m	
	$\left({}^{1}h_x + 1\right)$ (Dimensionless)	${}^{2}\left[\left(\Delta h_{R_{n-1}}\right)\left(\Delta h_x + 1\right)\right]$ (Dimensionless)	$\left({}^{1}h_x + 1\right)$ (Dimensionless)	${}^{2}\left[\left(\Delta h_{R_{n-1}}\right)\left(\Delta h_x + 1\right)\right]$ (Dimensionless)
35	1.0134	6.5463		
36	1.0129	6.6310		
37	1.0125	6.7140		
38	1.0121	6.7955		
39	1.0118	6.8754		
40	1.0114	6.9538		
41	1.0111	7.0308		
42	1.0108	7.1065		
43	1.0105	7.1809		
44	1.0102	7.2540		

1. $\left(h_x + 1\right)$-Relative rate of change of plume rise plus initial rise assumed as unity.
2. $\left[\left(\Delta h_{R_{n-1}}\right)\left(\Delta h_x + 1\right)\right]$--Accumulated relative rise.

Table 6

ACCUMULATED RELATIVE PLUME RISE - GALLATIN POWER PLANT

152-METER STACK

Distance Intervals (152 m)	Average Potential Temperature Gradient = 0.12° C/100 m		Average Potential Temperature Gradient = 0.77° C/100 m	
	$(^1h_x + 1)$ (Dimensionless)	$^2[(\Delta h_{R_{n-1}})(\Delta h_x + 1)]$ (Dimensionless)	$(^1h_x + 1)$ (Dimensionless)	$^2[(\Delta h_{R_{n-1}})(\Delta h_x + 1)]$ (Dimensionless)
1	1.0000	1.0000	1.0000	1.0000
2	1.5580	1.5580	1.6093	1.6093
3	1.3142	2.0474	1.2774	2.0557
4	1.2090	2.4753	1.1587	2.3820
5	1.1524	2.8525	1.1029	2.6271
6	1.1177	3.1882	1.0723	2.8170
7	1.0946	3.4898	1.0536	2.9679
8	1.0783	3.7630	1.0413	3.0906
9	1.0663	4.0123	1.0329	3.1923
10	1.0571	4.2413	1.0268	3.2779
11	1.0499	4.4528	1.0223	3.3510
12	1.0441	4.6491	1.0188	3.4141
13	1.0394	4.8321	1.0161	3.4691
14	1.0354	5.0033	1.0140	3.5175
15	1.0321	5.1641	1.0122	3.5605
16	1.0293	5.3156	1.0108	3.5988
17	1.0269	5.4586		
18	1.0248	5.5941		
19	1.0230	5.7227		
20	1.0214	5.8451		
21	1.0200	5.9617		
22	1.0187	6.0731		
23	1.0175	6.1796		
24	1.0165	6.2816		
25	1.0156	6.3795		
26	1.0147	6.4736		
27	1.0140	6.5640		
28	1.0133	6.6512		
29	1.0126	6.7352		
30	1.0120	6.8163		
31	1.0115	6.8946		
32	1.0110	6.9703		
33	1.0105	7.0436		
34	1.0101	7.1147		

1. $(h_x + 1)$-Relative rate of change of plume rise plus initial rise assumed as unity.
2. $[(\Delta h_{R_{n-1}})(\Delta h_x + 1)]$--Accumulated relative rise.

Table 7

ACCUMULATED RELATIVE PLUME RISE - BULL RUN POWER PLANT

244-METER STACK

Distance Intervals (152 m)	Average Potential Temperature Gradient = 0.23° C/100 m		Average Potential Temperature Gradient = 0.94° C/100 m	
	$\left({}^{1}h_x + 1\right)$ (Dimensionless)	${}^{2}\left[\left(\Delta h_{R_{n-1}}\right)\left(\Delta h_x + 1\right)\right]$ (Dimensionless)	$\left({}^{1}h_x + 1\right)$ (Dimensionless)	${}^{2}\left[\left(\Delta h_{R_{n-1}}\right)\left(\Delta h_x + 1\right)\right]$ (Dimensionless)
1	1.0000	1.0000	1.0000	1.0000
2	1.5151	1.5151	1.3270	1.3270
3	1.2865	1.9493	1.1478	1.5232
4	1.1869	2.3177	1.0842	1.6514
5	1.1390	2.6349	1.0544	1.7412
6	1.1051	2.9119	1.0381	1.8075
7	1.0841	3.1569	1.0282	1.8584
8	1.0693	3.3758	1.0217	1.8987
9	1.0585	3.5732	1.0172	1.9314
10	1.0502	3.7526	1.0140	1.9584
11	1.0437	3.9167	1.0116	1.9812
12	1.0386	4.0678		
13	1.0344	4.2075		
14	1.0309	4.3374		
15	1.0279	4.4585		
16	1.0254	4.5720		
17	1.0233	4.7685		
18	1.0215	4.7789		
19	1.0198	4.8737		
20	1.0184	4.9635		
21	1.0172	5.0487		
22	1.0160	5.1297		
23	1.0150	5.2069		
24	1.0142	5.2806		
25	1.0133	5.3510		
26	1.0126	5.4185		
27	1.0119	5.4831		
28	1.0113	5.5452		
29	1.0108	5.6049		
30	1.0102	5.6623		

1. $\left(h_x + 1\right)$-Relative rate of change of plume rise plus initial rise assumed as unity.
2. $\left[\left(\Delta h_{R_{n-1}}\right)\left(\Delta h_x + 1\right)\right]$--Accumulated relative rise.

Table 8

MAXIMUM ACCUMULATED RELATIVE RISE

BY STACK HEIGHTS

Power Plant	Stack Height (meters)	Potential Temperature Gradient (°C/100 m)	Downwind Interval (152 m)	Maximum Accumulated Relative Rise (Dimensionless)
Paradise	183	0.0095	44	7.2540
	183	0.47	29	4.8805
Gallatin	152	0.12	34	7.1147
	152	0.77	16	3.5988
Bull Run	244	0.23	30	5.6623
	244	0.94	11	1.9812

Table 9

AVERAGE PLUME RISE DATA SEPARATED INTO THREE STABILITY GROUPS

(COMBINED STACK HEIGHTS)

Group	Pot. Temp. Gradient Range (°C/100 m)	Avg. Pot. Temp. Gradient (°C/100 m)	Type of Data	Intervals of Distance (152 meters)											
				1	2	3	4	5	6	7	8	9	10	11	12
1	$0.70 < \frac{\Delta\theta}{\Delta_z} \leq 1.87$	1.06	1	364	354	346	322	281	266	256	125	64	30	19	15
			2	46	46	45	45	41	38	36	22	14	9	8	5
			3	1.0000	1.3548	1.5876	1.7171	1.8370	1.9072	1.9650	2.0510	2.1425	2.3000	2.5650	2.6932
			4		0.3548	0.1718	0.0816	0.0698	0.0382	0.0304	0.0437	0.0446	0.0735	0.1152	0.0508
2	$0.16 < \frac{\Delta\theta}{\Delta_z} \leq .70$	0.43	1	389	373	355	335	300	256	204	111	87	66	20	14
			2	48	46	46	46	42	40	35	21	18	16	7	5
			3	1.0000	1.4274	1.7400	1.9928	2.2700	2.4799	2.6742	2.8800	3.0787	3.3911	3.6774	4.0428
			4		0.4274	0.2190	0.1453	0.1391	0.0925	0.0783	0.0770	0.0691	0.1014	0.0844	0.0994
3	$-0.17 < \frac{\Delta\theta}{\Delta_z} \leq 0.16$	0.05	1	454	435	406	329	275	227	158	86	54	38	26	18
			2	46	46	46	43	41	39	29	20	17	13	9	7
			3	1.0000	1.4488	1.8198	2.1703	2.4768	2.7550	2.9928	3.0991	3.6201	3.9267	4.4097	4.6149
			4		0.4488	0.2561	0.1926	0.1412	0.1123	0.0863	0.0355	0.1681	0.0847	0.1230	0.0465

1. No. of Photographs.
2. No. of Composited Observations.
3. Relative Accumulated Rise.
4. Relative Rate of Change of Plume Rise.

Table 10

ACCUMULATED RELATIVE PLUME RISE

(COMBINED STACKS)

Distance Intervals (152 m)	Avg. Pot. Temp. Gradient = 0.05° C/100 m		Avg. Pot. Temp. Gradient = 0.43° C/100 m		Avg. Pot. Temp. Gradient = 1.06° C/100 m	
	$(^1h_x + 1)$ (Dimensionless)	$^2[(\Delta h_{Rn-1})(\Delta h_x + 1)]$ (Dimensionless)	$(^1h_x + 1)$ (Dimensionless)	$^2[(\Delta h_{Rn-1})(\Delta h_x + 1)]$ (Dimensionless)	$(^1h_x + 1)$ (Dimensionless)	$^2[(\Delta h_{Rn-1})(\Delta h_x + 1)]$ (Dimensionless)
1	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
2	1.4454	1.4454	1.4020	1.4040	1.3610	1.3610
3	1.2663	1.8304	1.2359	1.7326	1.1622	1.5818
4	1.1849	2.1688	1.1616	2.0126	1.0920	1.7272
5	1.1393	2.4709	1.1205	2.2552	1.0592	1.8295
6	1.1105	2.7441	1.0948	2.4691	1.0413	1.9051
7	1.0909	2.9935	1.0774	2.6603	1.0305	1.9631
8	1.0767	3.2233	1.0650	2.8331	1.0234	2.0091
9	1.0661	3.4363	1.0557	2.9908	1.0186	2.0464
10	1.0578	3.6350	1.0485	3.1357	1.0151	2.0773
11	1.0512	3.8212	1.0427	3.2697	1.0125	2.1032
12	1.0459	3.9965	1.0381	3.3944	1.0105	2.1354
13	1.0415	4.1622	1.0343	3.5109		
14	1.0377	4.3192	1.0311	3.6202		
15	1.0346	4.4685	1.0284	3.7231		
16	1.0319	4.6109	1.0261	3.8203		
17	1.0295	4.7469	1.0241	3.9125		
18	1.0274	4.8771	1.0224	4.0000		
19	1.0256	5.0020	1.0208	4.0834		
20	1.0240	5.1220	1.0195	4.1629		
21	1.0226	5.2376	1.0183	4.2390		
22	1.0213	5.3490	1.0172	4.3118		
23	1.0201	5.4565	1.0162	4.3817		
24	1.0190	5.5604	1.0153	4.4489		
25	1.0181	5.6609	1.0145	4.5135		

1. $(h_x + 1)$--Relative rate of change of plume rise plus initial rise assumed as unity.

2. $\left[(\Delta h_{Rn-1})\ (\Delta h_x + 1)\right]$ --Accumulated relative rise.

TABLE 10 (CONTINUED)

Distance Intervals (152 m)	Avg. Pot. Temp. Gradient = 0.05° C/100 m		Avg. Pot. Temp. Gradient = 0.43° C/100 m		Avg. Pot. Temp. Gradient = 1.06° C/100 m	
	$(^1h_x + 1)$ (Dimensionless)	$^2[(\Delta h_{R_{n-1}})(\Delta h_x + 1)]$ (Dimensionless)	$(^1h_x + 1)$ (Dimensionless)	$^2[(\Delta h_{R_{n-1}})(\Delta h_x + 1)]$ (Dimensionless)	$(^1h_x + 1)$ (Dimensionless)	$^2[(\Delta h_{R_{n-1}})(\Delta h_x + 1)]$ (Dimensionless)
26	1.0172	5.7583	1.0138	4.5758		
27	1.0164	5.8528	1.0131	4.6359		
28	1.0157	5.9444	1.0125	4.6939		
29	1.0150	6.0335	1.0120	4.7500		
30	1.0143	6.1200	1.0114	4.8043		
31	1.0138	6.2043	1.0109	4.8569		
32	1.0132	6.2863	1.0105	4.9079		
33	1.0127	6.3662	1.0101	4.9574		
34	1.0122	6.4441				
35	1.0118	6.5205				
36	1.0114	6.5944				
37	1.0110	6.6669				
38	1.0106	6.7378				
39	1.0103	6.8071				

1. $(h_x + 1)$--Relative rate of change of plume rise plus initial rise assumed as unity.

2. $[(\Delta h_{R_{n-1}})(\Delta h_x + 1)]$ --Accumulated relative rise.

Table 11

SUMMARY OF K VALUES FOR $\Delta h_1 = K \frac{F^{1/3}}{\bar{u}}$

Potential Temperature Gradient (°C/100 m)	K ($m^{2/3}$)
0.05	43.24
0.43	43.14
1.06	43.13
Average All Data	43.18

$$\Delta h_1 = 43 \frac{F^{1/3}}{\bar{u}}$$

Table 12

Δh_{R_n} - ACCUMULATED RELATIVE RISE (DIMENSIONLESS)

Downwind Distance (m)	Interval of Distance (152 m)	Neutral[1]	Moderately Stable[2]	Very Stable[3]
152	1	1.0000	1.0000	1.0000
304	2	1.4454	1.4020	1.3610
456	3	1.8304	1.7326	1.5818
608	4	2.1688	2.0126	1.7272
760	5	2.4709	2.2552	1.8295
912	6	2.7441	2.4691	1.9051
1,064	7	2.9935	2.6603	1.9631
1,216	8	3.2233	2.8331	2.0091
1,368	9	3.4363	2.9908	2.0464
1,520	10	3.6350	3.1357	2.0773
1,672	11	3.8212	3.2697	2.1032
1,824	12	3.9965	3.3944	2.1254
1,976	13	4.1622	3.5109	2.1445
2,128	14	4.3192	3.6202	2.1612
2,280	15	4.4685	3.7231	2.1758
2,432	16	4.6109	3.8203	2.1888
2,584	17	4.7469	3.9125	2.2004
2,736	18	4.8771	4.0000	2.2107
2,888	19	5.0020	4.0834	2.2201
3,040	20	5.1220	4.1629	2.2286
3,192	21	5.2376	4.2390	2.2364
3,344	22	5.3490	4.3118	2.2435
3,496	23	5.4565	4.3817	2.2500
3,648	24	5.5604	4.4489	2.2560
3,800	25	5.6609	4.5135	2.2616
3,952	26	5.7583	4.5758	2.2668
4,102	27	5.8528	4.6359	2.2716
4,256	28	5.9444	4.6939	2.2761
4,408	29	6.0335	4.7500	2.2803
4,560	30	6.1200	4.8043	2.2842
4,712	31	6.2043	4.8569	
4,864	32	6.2863	4.9079	
5,016	33	6.3662	4.9574	
5,168	34	6.4441		
5,320	35	6.5202		
5,472	36	6.5944		
5,624	37	6.6669		
5,776	38	6.7378		
5,928	39	6.8071		
6,080	40	6.8672		

1. Neutral ($-0.17 < \frac{\Delta\theta}{\Delta z} \leq 0.16$° C/100 m, average = 0.05° C/100 m)
2. Moderately Stable ($0.16 < \frac{\Delta\theta}{\Delta z} \leq 0.70$° C/100 m, average = 0.43° C/100 m)
3. Very Stable ($0.70 < \frac{\Delta\theta}{\Delta z} \leq 1.87$° C/100 m, average = 1.06° C/100 m)

Effective Plume Rise: $\Delta h = \Delta h_R \, 43 \, \frac{F^{1/3}}{\bar{u}}$

TENNESSEE VALLEY AUTHORITY
Division of Environmental Research and Development

APPENDIX B

FIGURES

Muscle Shoals, Alabama
October 1971

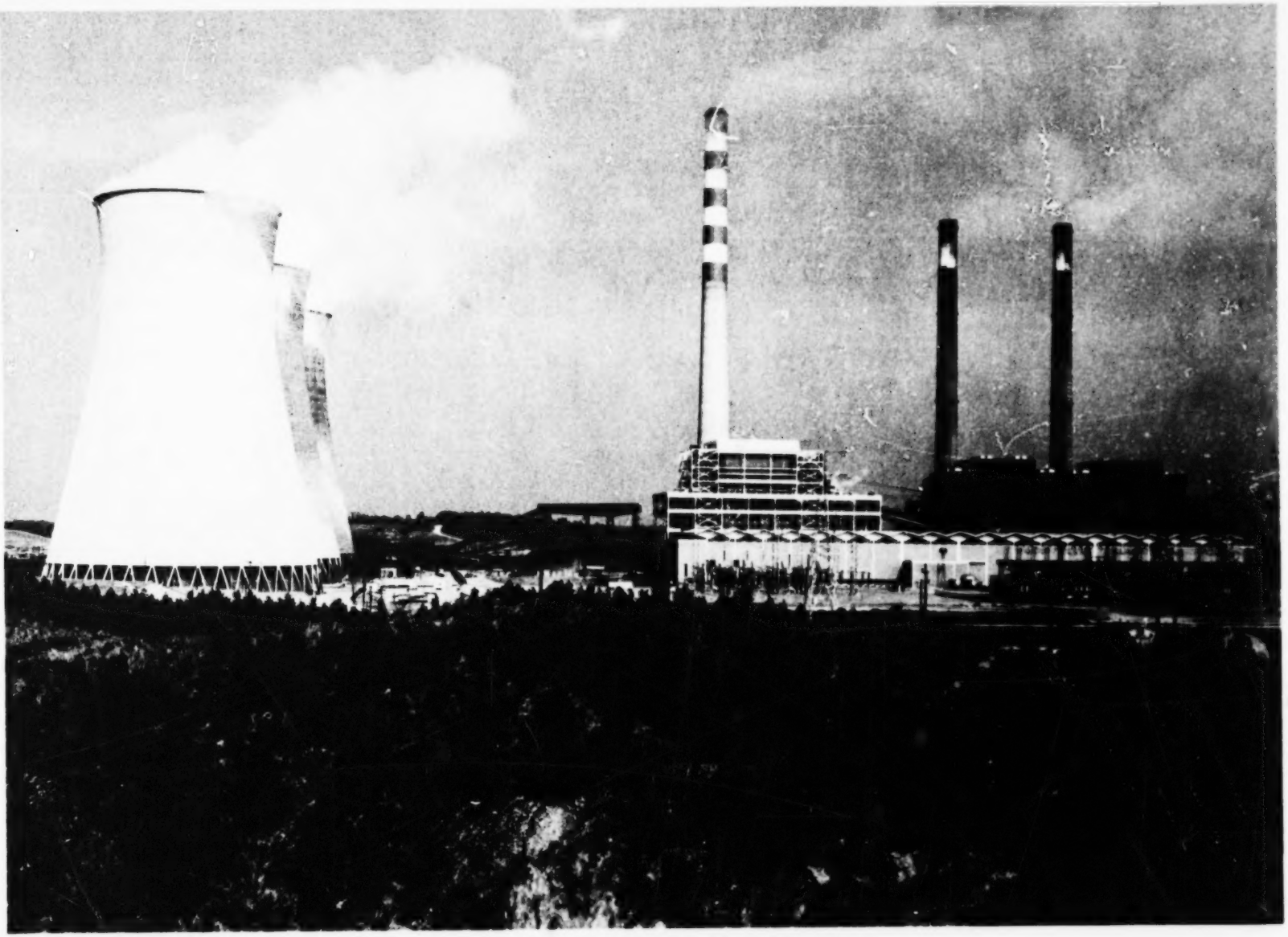


FIGURE 1. PARADISE POWER PLANT

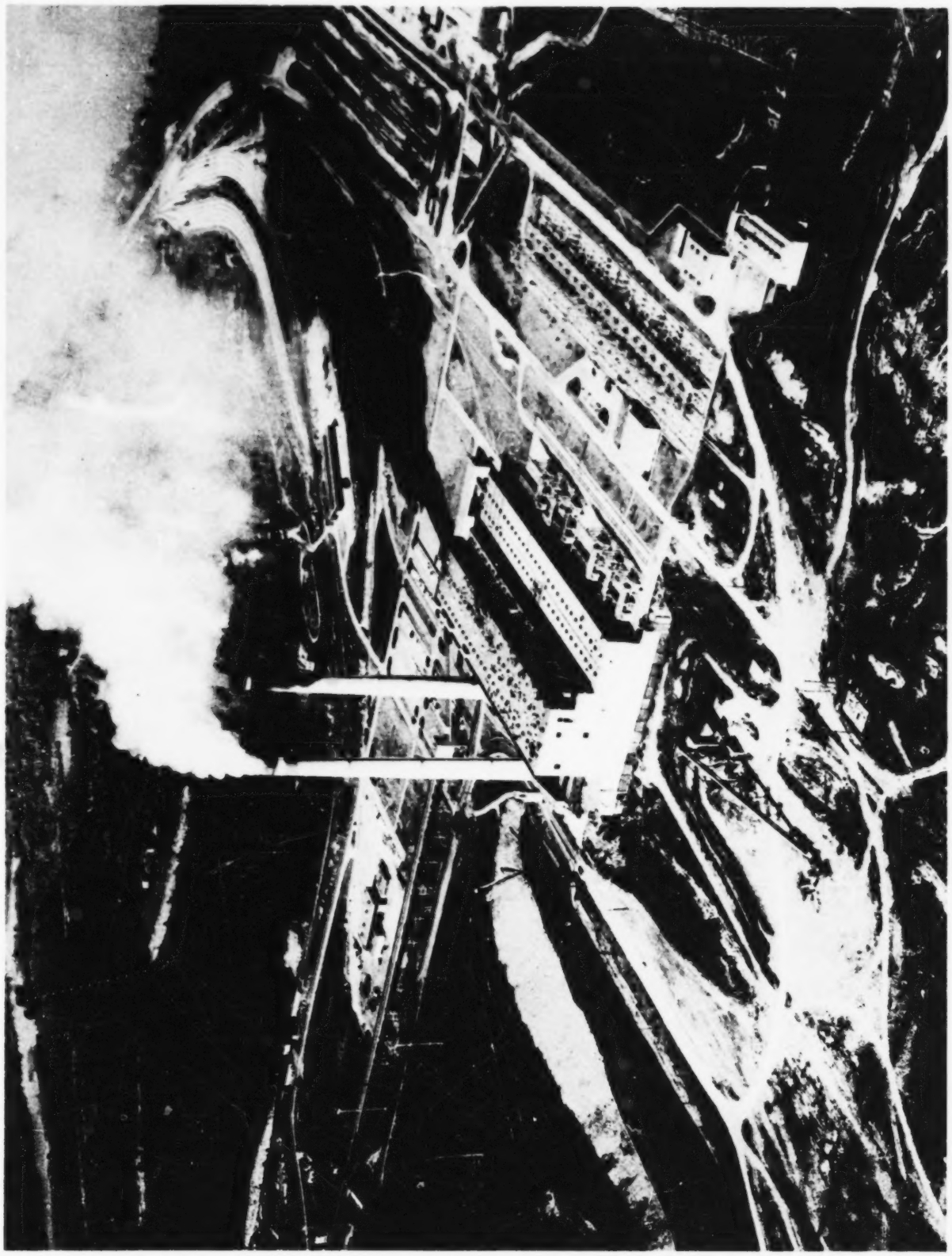
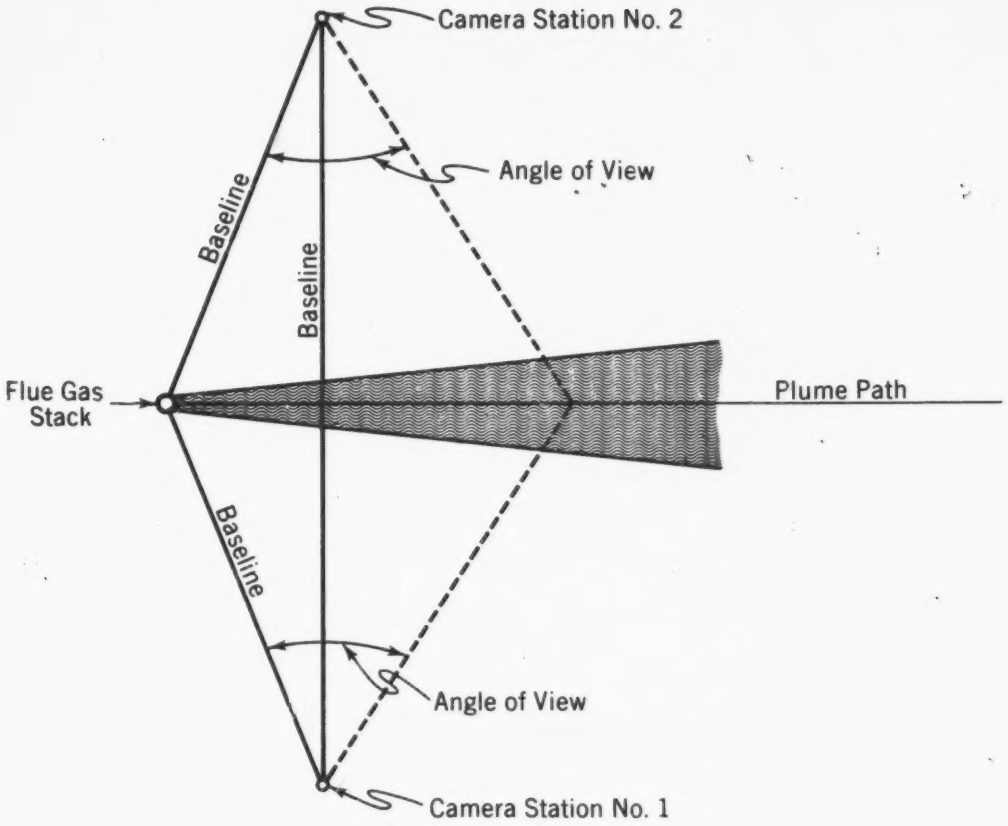
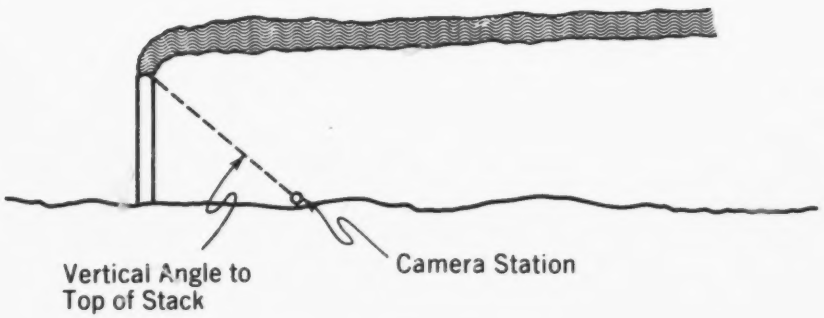


FIGURE 2. GALLATIN POWER PLANT

FIGURE 3. BULL RUN POWER PLANT



A. PLAN VIEW



B. PROFILE VIEW

Figure 4. PLUME PHOTOGRAPHIC PLAN BY TWO CAMERAS

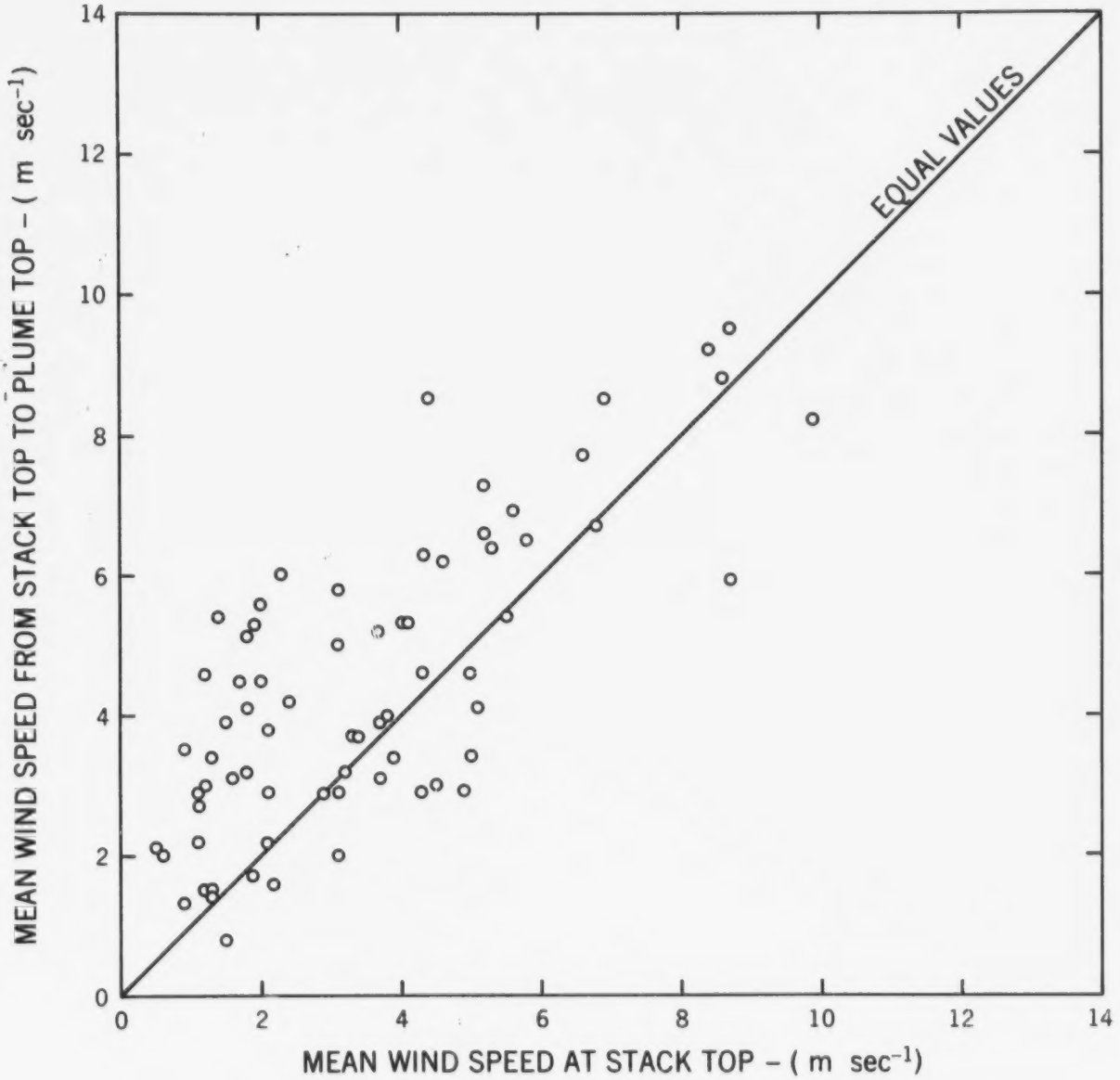


Figure 5. MEAN WIND SPEED FROM STACK TOP TO PLUME TOP COMPARED TO MEAN WIND SPEED AT STACK TOP

BULL RUN POWER PLANT

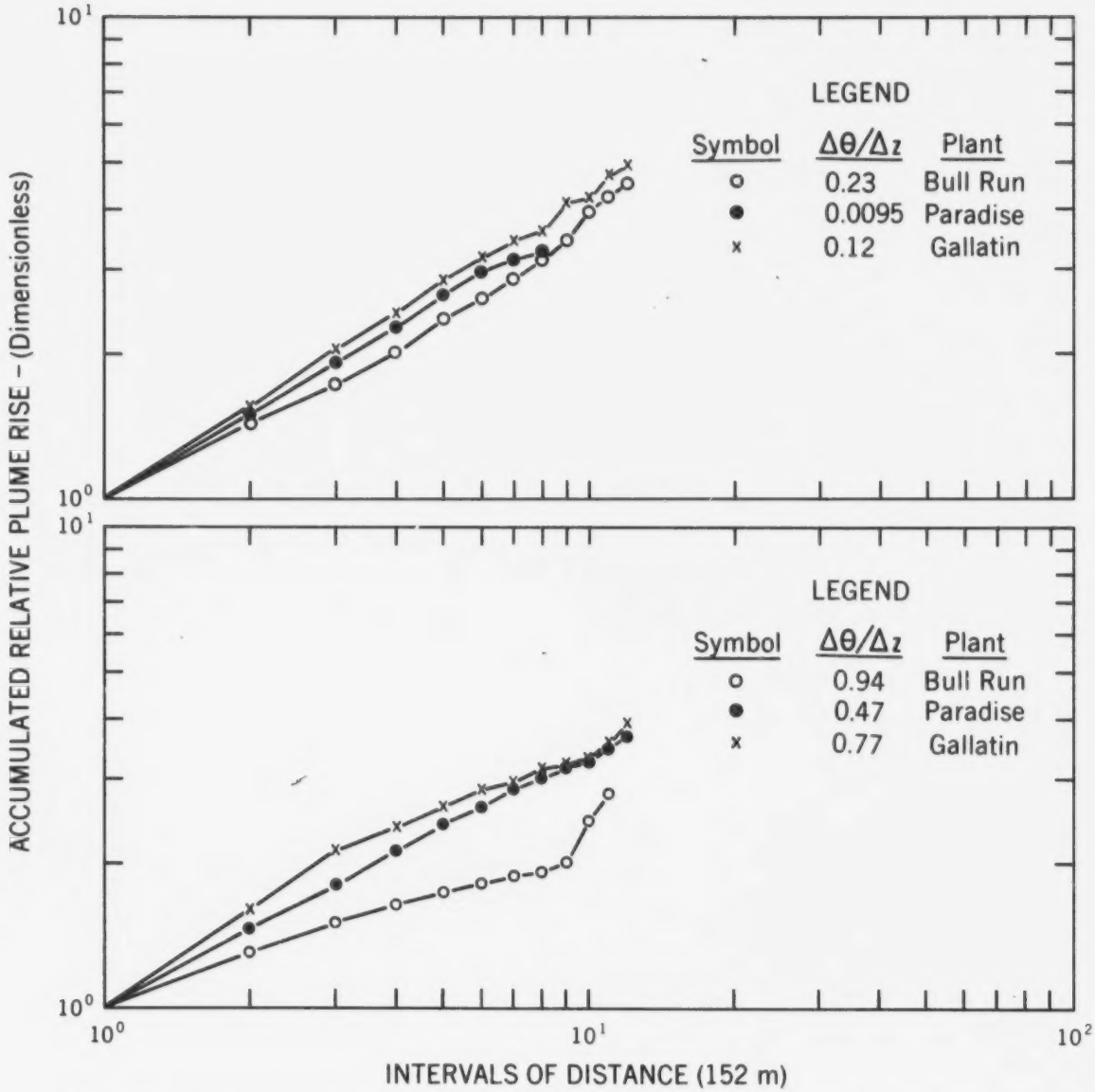


Figure 6. OBSERVED ACCUMULATED RELATIVE PLUME RISE VERSUS DISTANCE SEPARATE STACK HEIGHTS

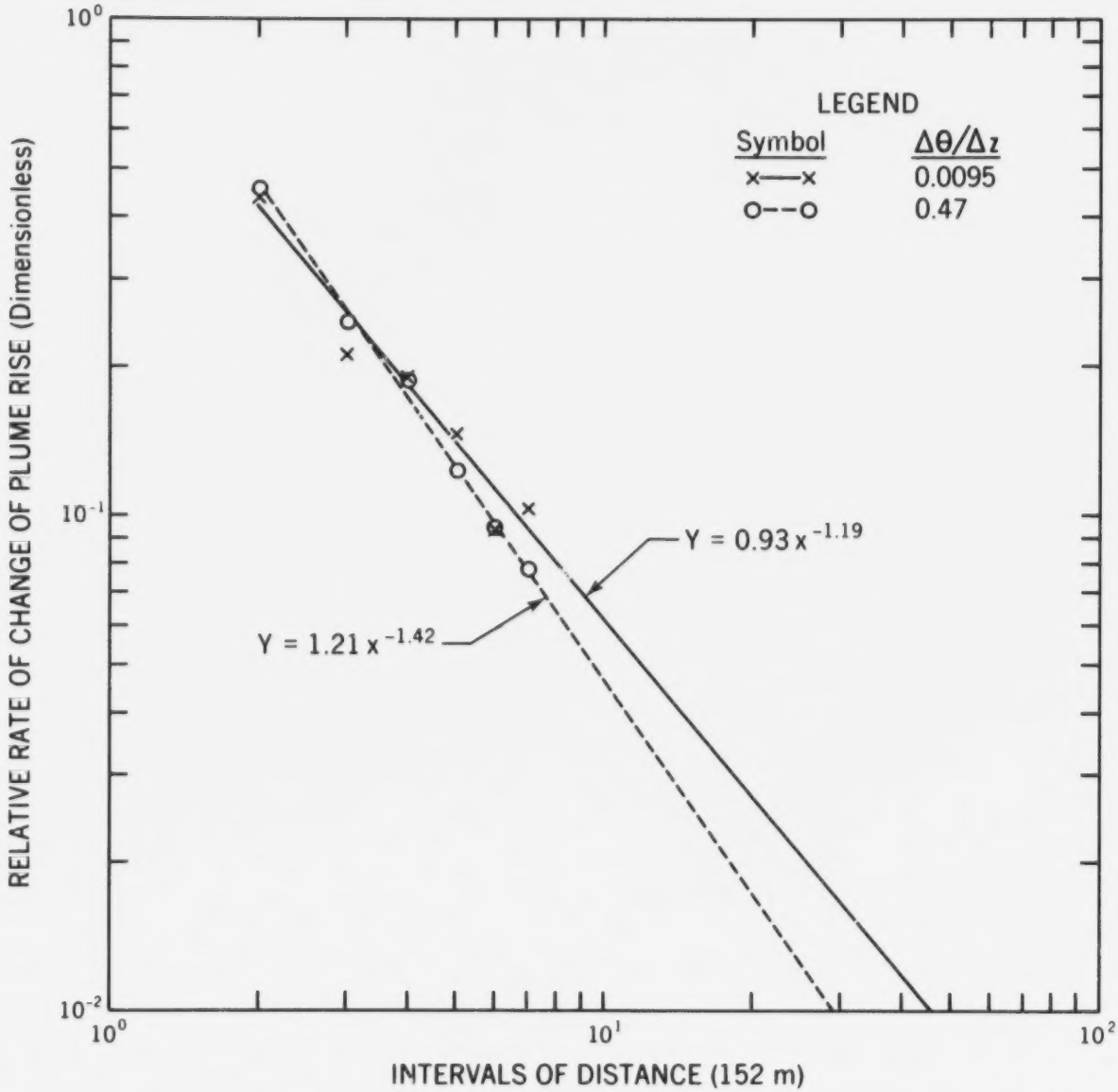


Figure 7. OBSERVED RELATIVE RATE OF CHANGE OF PLUME RISE WITH DISTANCE PARADISE POWER PLANT

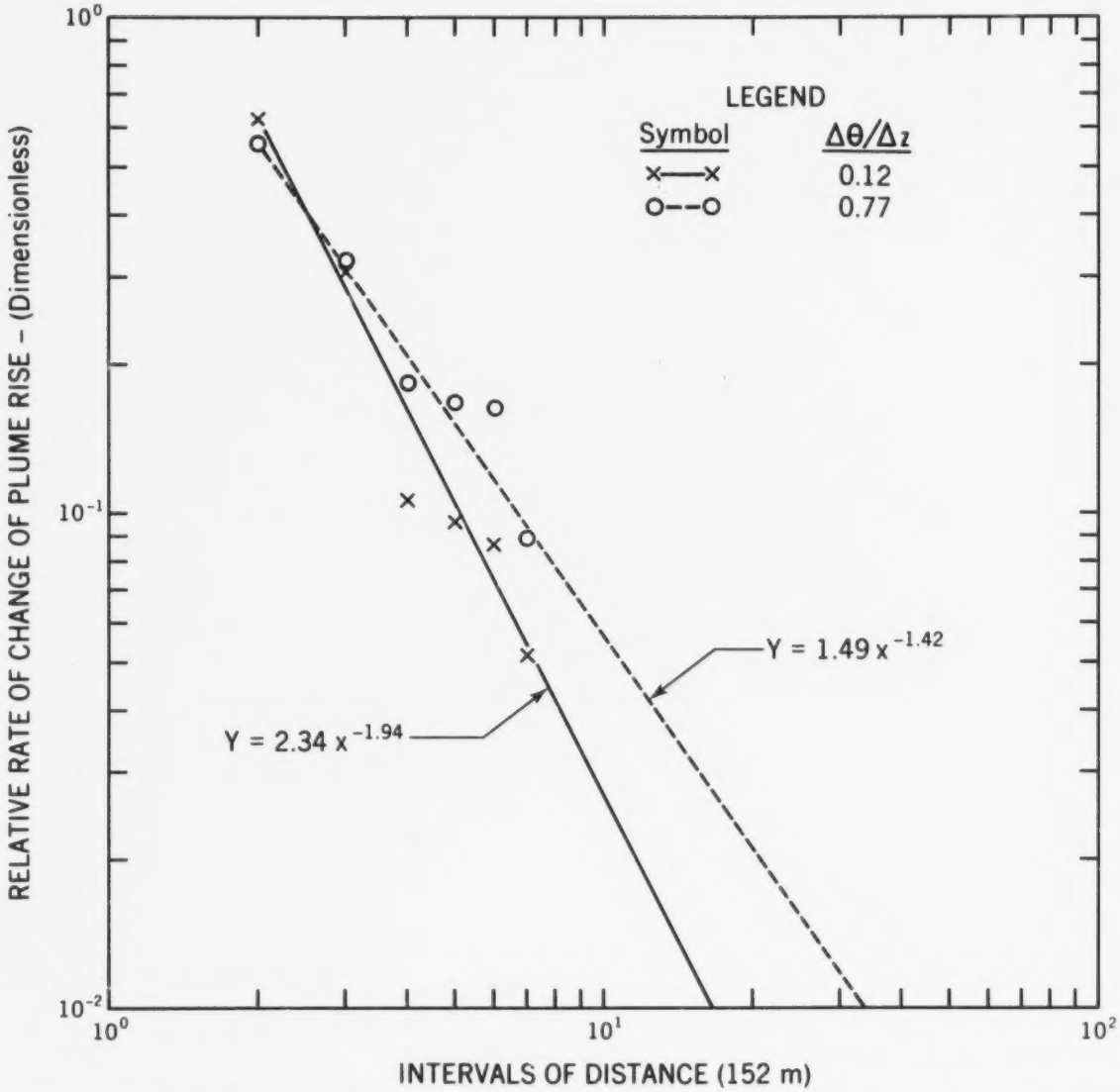


Figure 8. OBSERVED RELATIVE RATE OF CHANGE OF PLUME RISE WITH DISTANCE GALLATIN POWER PLANT

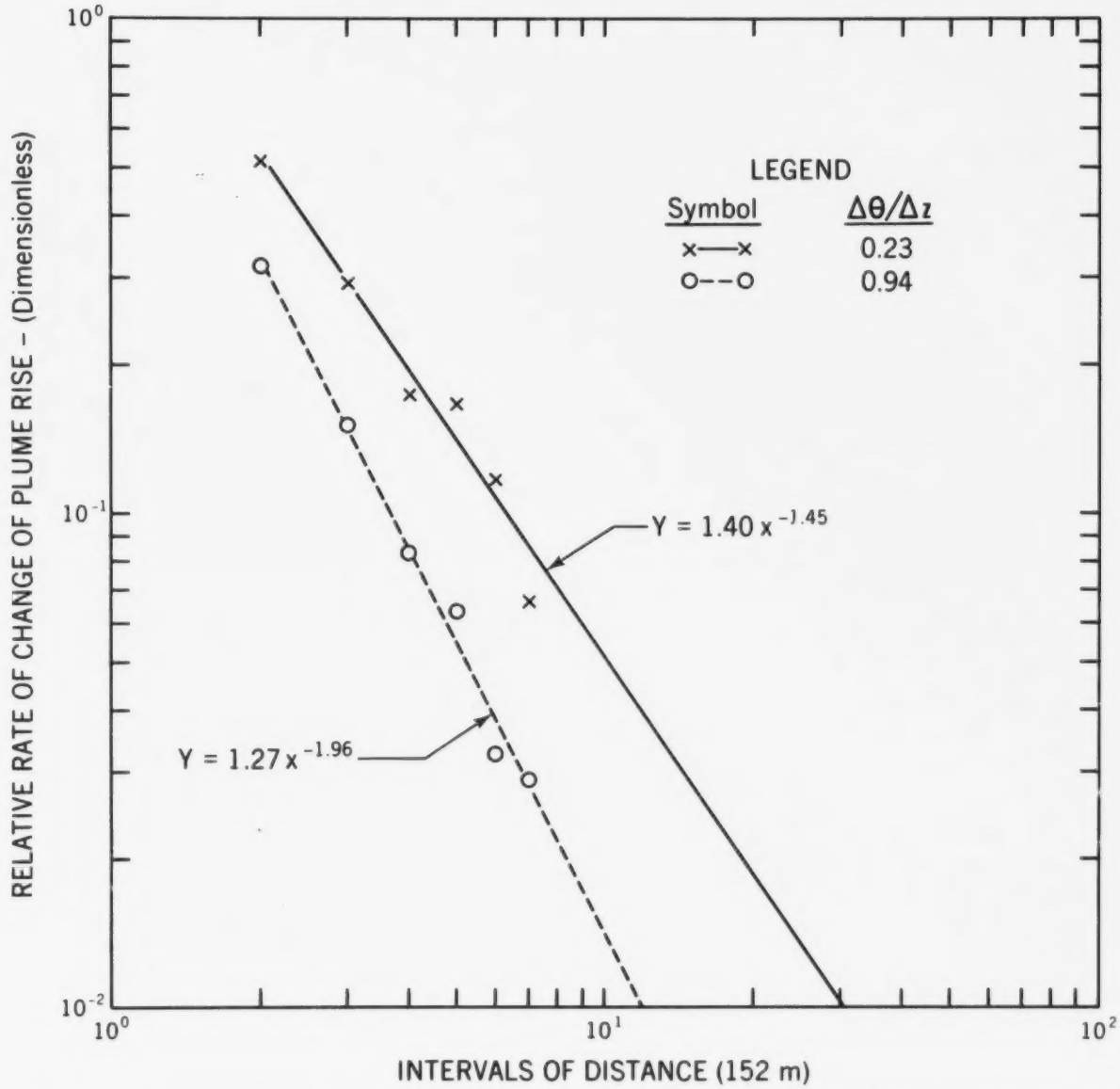


Figure 9. OBSERVED RELATIVE RATE OF CHANGE OF PLUME RISE WITH DISTANCE BULL RUN POWER PLANT

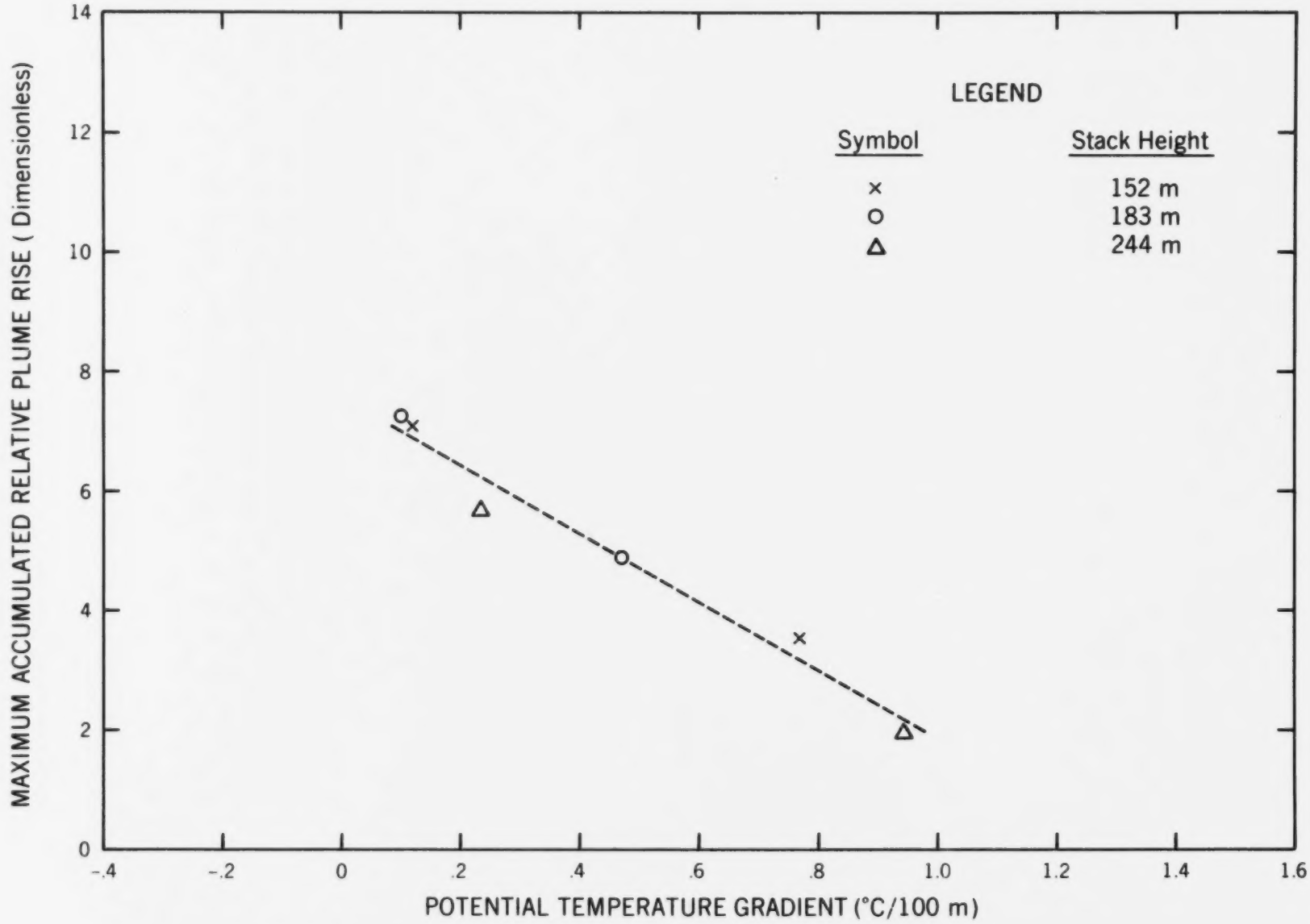


Figure 10. MAXIMUM ACCUMULATED RELATIVE PLUME RISE VERSUS STABILITY

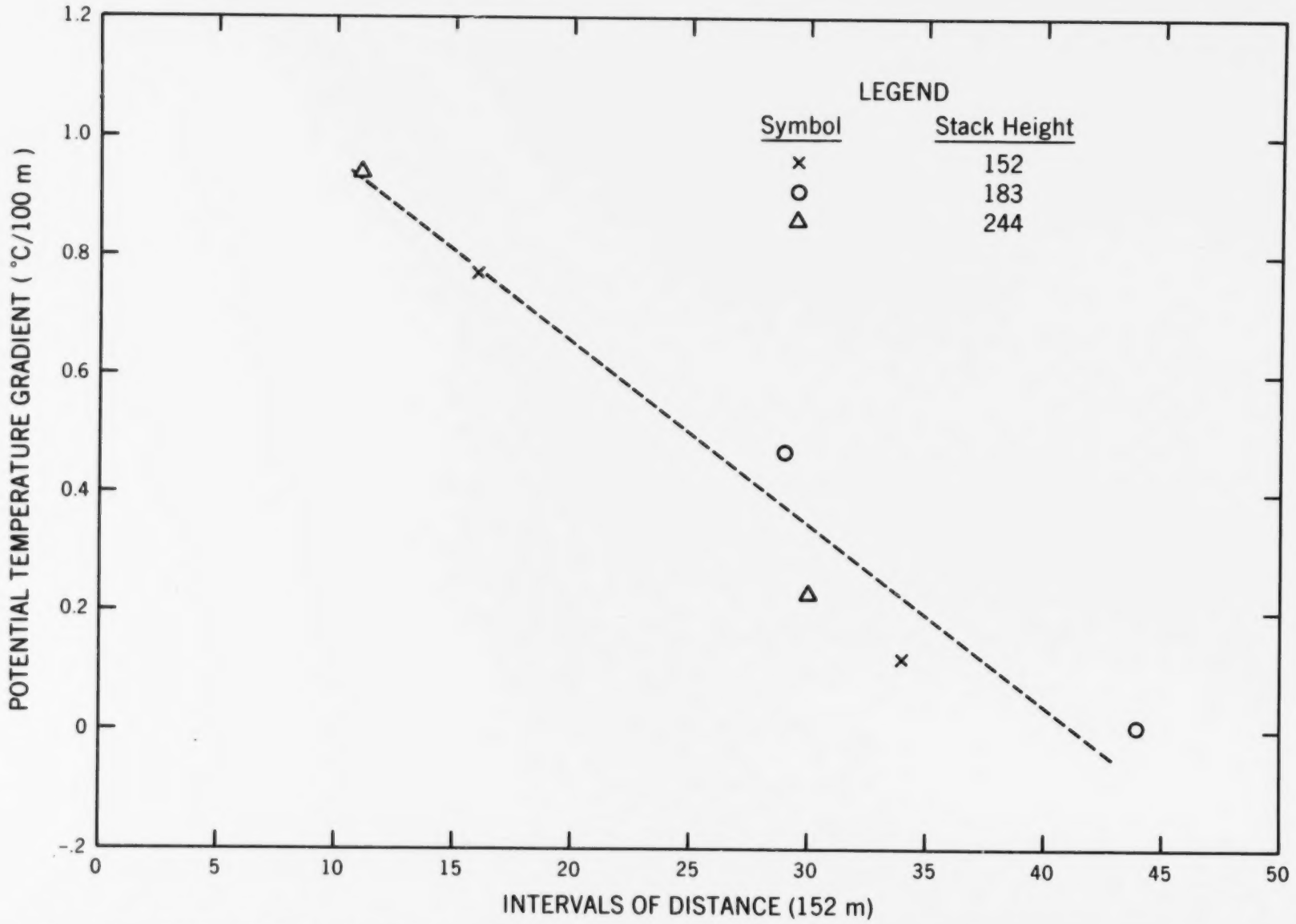


Figure 11. DISTANCE TO POINT OF MAXIMUM ACCUMULATED RELATIVE PLUME RISE VERSUS STABILITY

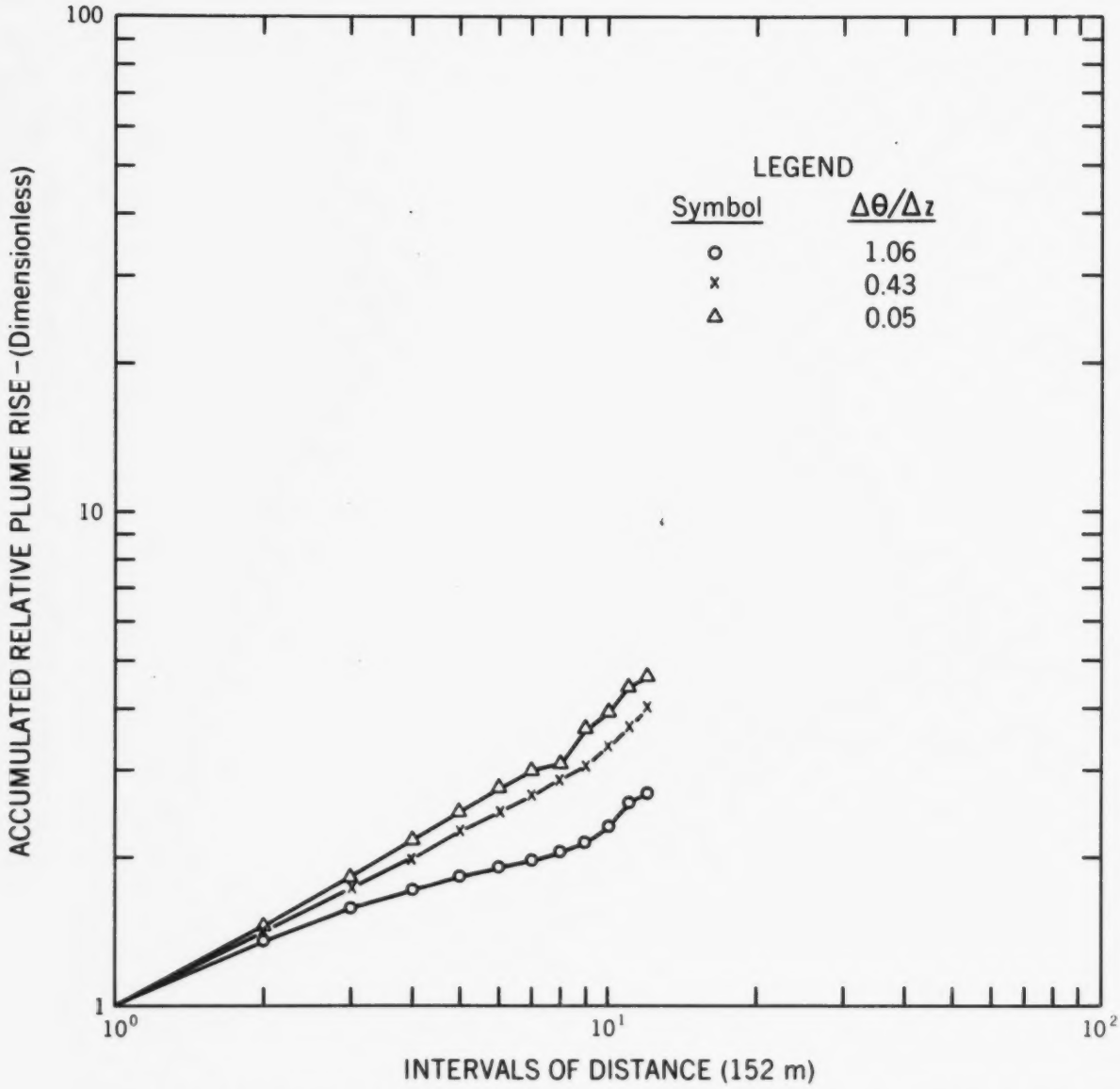


Figure 12. OBSERVED ACCUMULATED RELATIVE PLUME RISE VERSUS DISTANCE COMBINED STACK HEIGHTS

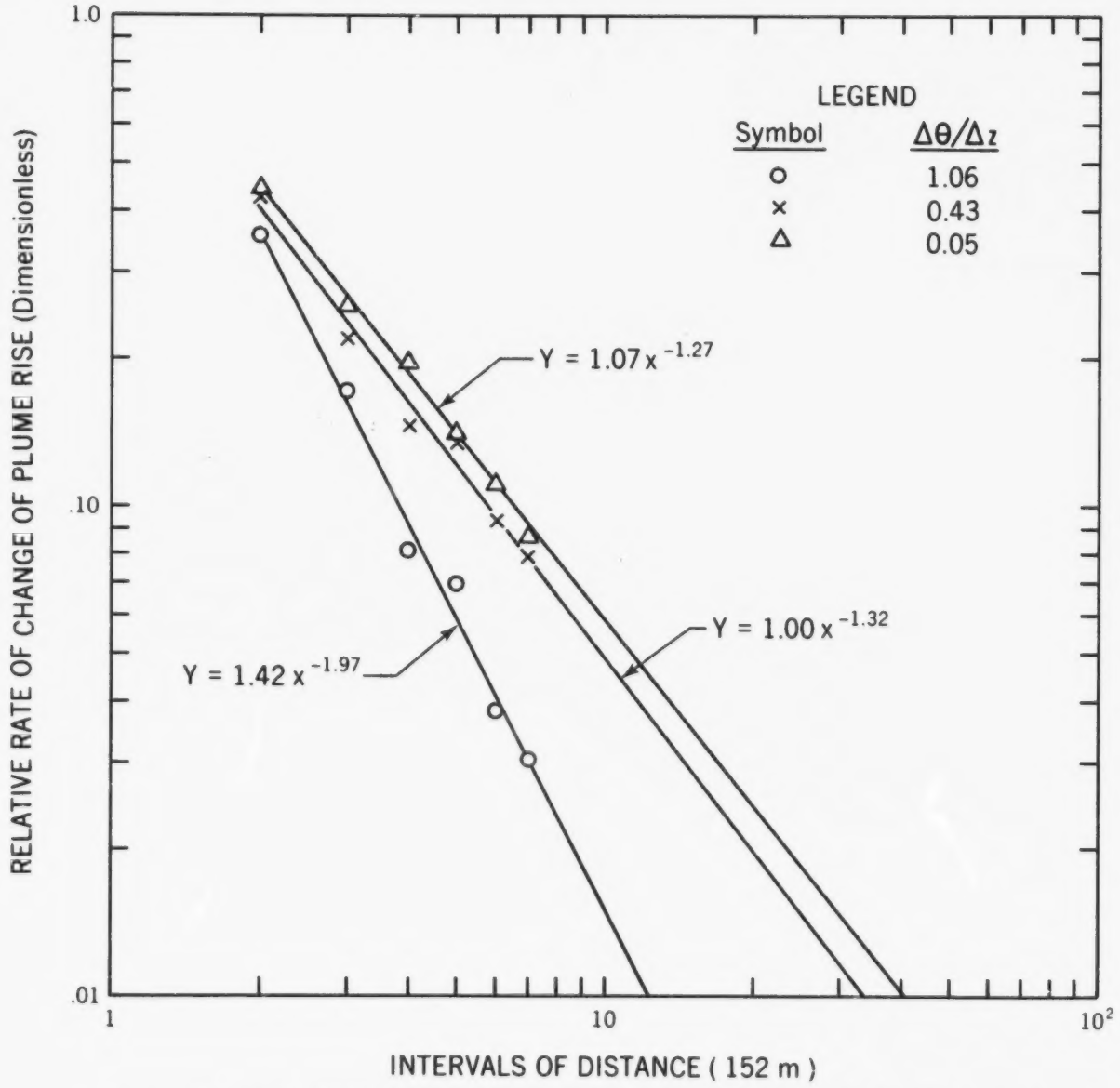


Figure 13. RELATIVE RATE OF CHANGE OF PLUME RISE WITH DISTANCE COMBINED STACK HEIGHTS

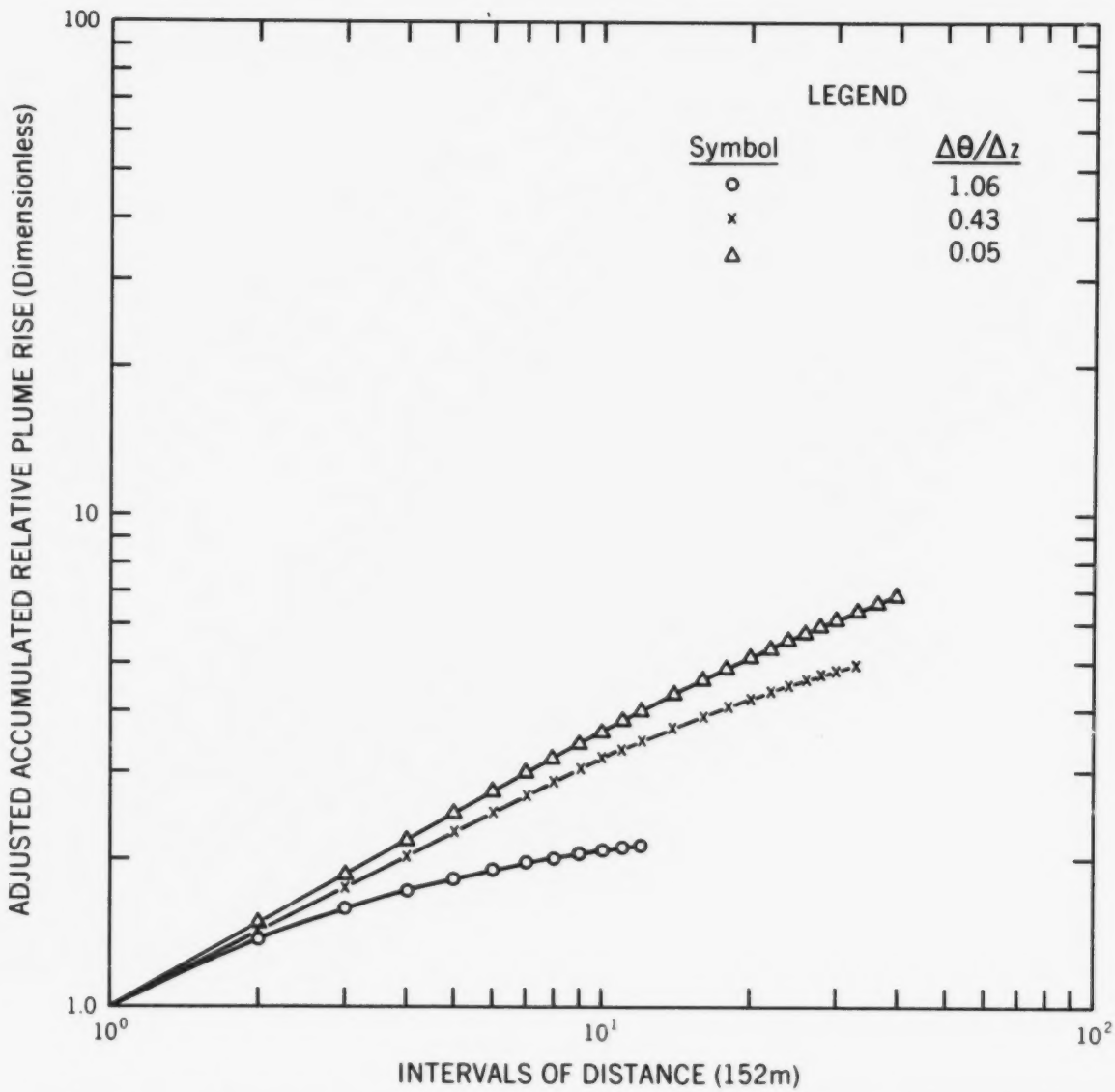


Figure 14. ADJUSTED ACCUMULATED RELATIVE PLUME RISE VERSUS DISTANCE

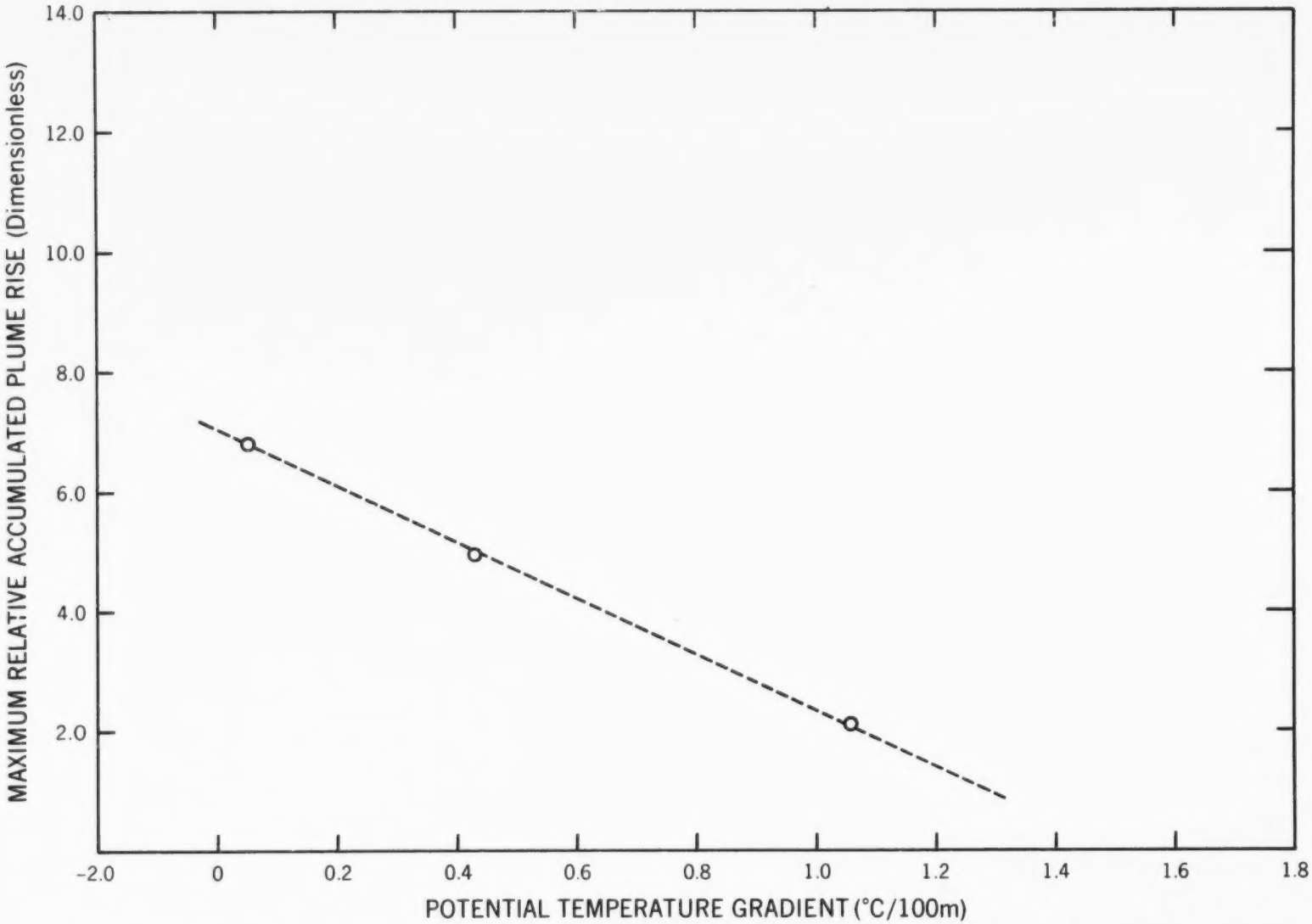


Figure 15. ADJUSTED MAXIMUM ACCUMULATED RELATIVE PLUME RISE VERSUS STABILITY COMBINED STACK HEIGHTS

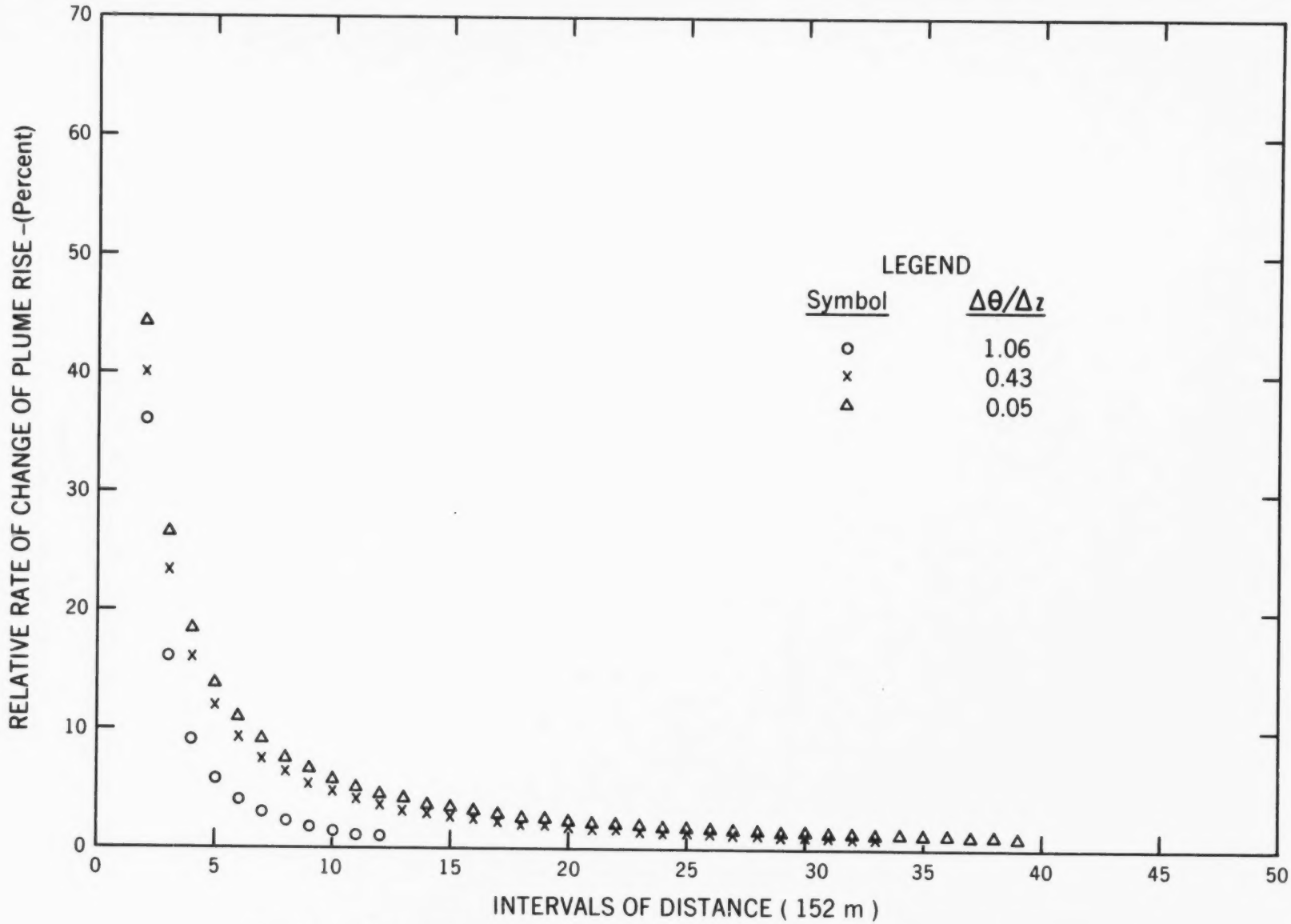


Figure 16. PERCENT RATE OF CHANGE OF PLUME RISE WITH DISTANCE

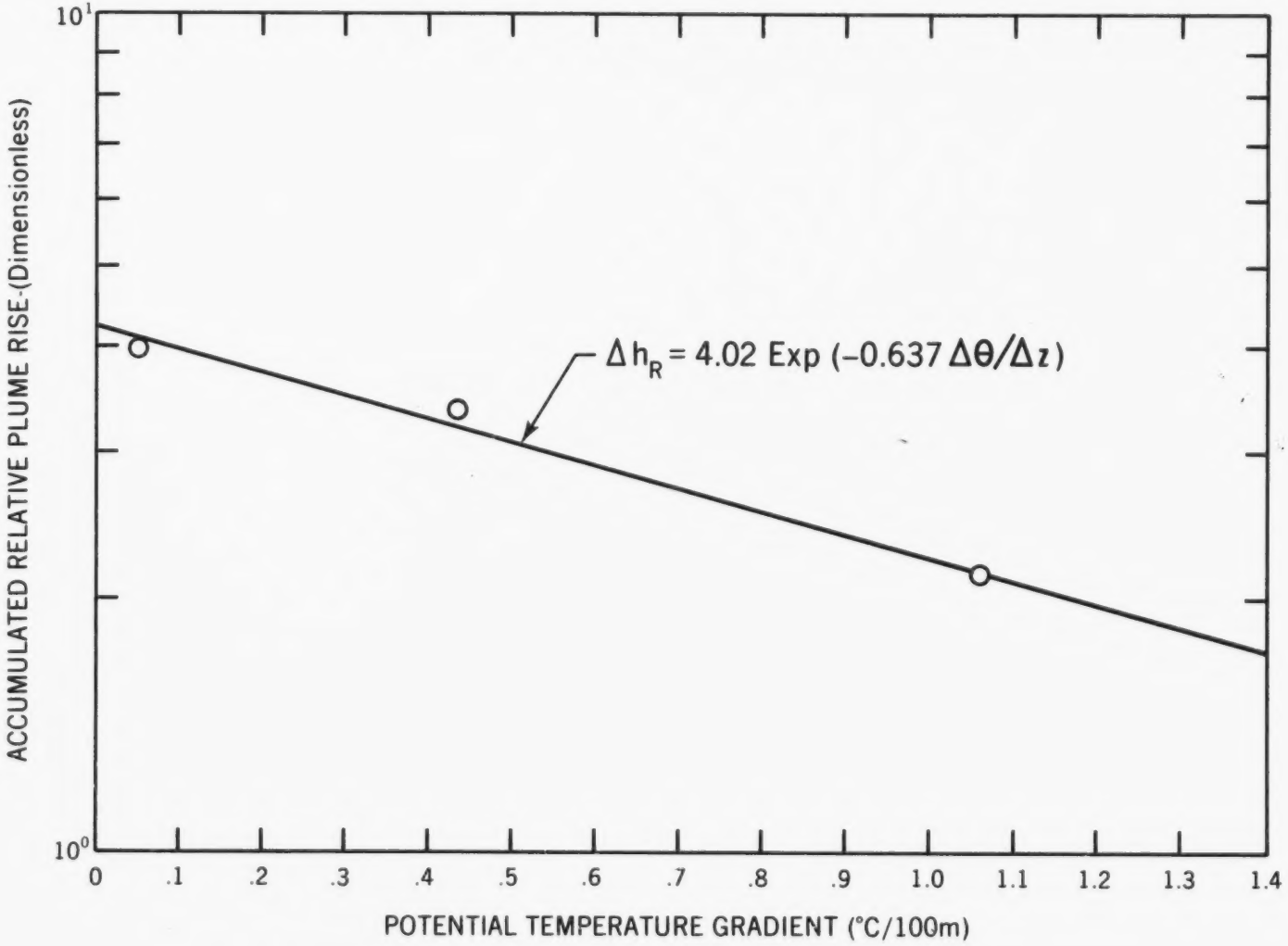


Figure 17. ACCUMULATED RELATIVE PLUME RISE VERSUS STABILITY